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DEVELOPMENT OF A SOLID ROCKET PRO-  
PELLANT NONLINEAR VISCOELASTIC  
CONSTITUTIVE THEORY. VOLUME 2.  
APPENDICES

Richard J. Farris, et al

Aerojet Solid Propulsion Company

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<p>This program was designed to develop three dimensional nonlinear viscoelastic equations that could describe the stress-strain response of solid propellant materials for complex loading conditions. The approach used was to identify and mathematically model the underlying mechanisms contributing to the constitutive nonlinearity and to then include these effects within the framework of a continuum constitutive theory.</p> <p>The program was successful in meeting its objectives and some of the program developments and conclusions are as follows. The dominant mechanisms leading to the nonlinear stress-strain response is microstructural damage in the form of the Mullins' stress-softening effect and vacuole dilatation. Reversible nonlinearities were found to be of secondary importance. These effects have been modeled and combined into a constitutive theory that works very well for fitting the distortional stress-strain behavior under complex loading conditions. This theory is a permanent memory constitutive theory and contains irreversible effects of the past history on the current response. Time effects are included through time-dependent structural damage as well as the ordinary viscous energy dissipation. The experimental work consisted of determining the three dimensional strain response due to complex stress histories at temperatures from -65°F to +150°F and superimposed hydrostatic stress-states from 0 to 1000 psi. To handle the large masses of data generated on this contract computerized characterization techniques were developed wherein the equations could be fit to large masses of data.</p>			

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DEVELOPMENT OF A SOLID ROCKET PROPELLANT NONLINEAR  
VISCOELASTIC CONSTITUTIVE THEORY

Volume II - Appendices

Prepared by:

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## FOREWORD

This program was sponsored by the

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The technical effort reported herein was accomplished under Contract F04611-71-C-0046 and covered the period from May 1971 through June 1973. Mr. Norman Walker was the Air Force project engineer at the start of this contract until he left AFRPL. Dr. Randy L. Peeters was the Air Force materials engineer for the remainder of this contract.

The program was completely successful in meeting its objectives. The success of the program was due to the combined efforts of key personnel at two facilities, the Aerojet Solid Propulsion Company and the Texas A&M Research Foundation. The Aerojet team performed an extensive experimental effort, developed computerized characterization techniques, and performed theoretical work in developing constitutive equations which accurately model the multi-axial behavior of composite propellants. The team at the Texas A&M Research Foundation supported the effort by performing theoretical and experimental work to develop mathematical models for characterizing solid propellants under realistic states of strain. The emphasis of their work was to develop simple constitutive equations based on thermodynamic principles for visco-elastic materials having microstructural damage.

The key technical personnel on this program were: Dr. Richard J. Farris who directed the Aerojet effort and coordinated the overall effort as the Program Technical Manager, and Dr. Richard A. Schapery who directed the Texas A&M effort. Mr. Frederick H. Davidson performed all of the experimental work at Aerojet and Mr. Dennis F. Vronay was primarily responsible for the computerized characterization work. Mr. L. E. Lewis and Mr. R. T. Shankle performed the Texas A&M experimental effort which was under the guidance of Mr. Scott Beckwith.

This technical report has been reviewed and is approved.

Dr. Randy L. Peeters (MKPB)  
Materials Engineer, AFRPL  
Edwards, California

## ABSTRACT

This program was designed to develop three dimensional nonlinear viscoelastic equations that could describe the stress-strain response of solid propellant materials for complex loading conditions. The approach used was to identify and mathematically model the underlying mechanisms contributing to the constitutive nonlinearity in these highly filled Polymeric materials and to then include these effects within the framework of a continuum constitutive theory. Also considerable theoretical work was done showing how the resulting mathematical representations could be contained within the framework of a thermodynamic theory and viscoelastic fracture mechanics. During the course of this contract considerable experimental as well as theoretical work were performed since the development of the theory was based on modeling observable effects. The experimental work consisted of determining the three dimensional strain response due to complex stress histories at temperatures from  $-65^{\circ}\text{F}$  to  $+150^{\circ}\text{F}$  and superimposed hydrostatic stress-states from 0 to 1000 psi. In total over 250 experiments were run using uniaxial and biaxial volumetric dilatometers and the stress-strain-strain invariant-time history of each experiment is stored on magnetic tape and can be made available for others to use.

The program was successful in meeting its objectives and some of the program developments and conclusions are as follows. The dominant mechanisms leading to the nonlinear stress-strain response is micro-structural damage in the form of the Mullins' stress-softening effect and vacuole dilatation. Reversible nonlinearities such as second order hereditary strain effects were found to be of secondary importance. These effects have been successfully modeled and combined into a relatively simple constitutive theory that works very well for fitting the distortional stress-strain behavior under complex loading conditions. This theory is a permanent memory constitutive theory and contains irreversible effects of the past history on the current response which are not included in the usual fading memory viscoelastic theories. Time effects are included in the permanent memory theory through time-dependent structural damage as well as the ordinary viscous energy dissipation. The bulk effects were also modeled and good agreement could be obtained only when the vacuole gas phase compressibility was included in the constitutive theory which resulted in a mixed stress-invariant-strain invariant representation. To handle the large masses of data generated on this contract computerized characterization techniques were developed wherein the equations could be fit to large masses of data to determine the applicability of the theory. For constant temperature conditions the theory could be fit within a standard deviation of  $\pm 12\%$  of the observed distortional stress data for approximately forty compTex experiments using the entire response curve to failure. The overall accuracy dropped when all the temperature data was analyzed together to about  $\pm 15\%$ . The bulk response predictions were poorer and typical deviations were  $\pm 25\%$  nevertheless all of the proper trends were in the predictions and much of these errors were no doubt experimental.

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## FOREWORD TO APPENDIX A

Appendix A, "Studies on the Nonlinear Viscoelastic Behavior of Solid Propellant," represents the final technical report from Texas A&M University subcontract effort to the Aerojet Solid Propulsion Company. The work at Texas A&M was performed under the direction of Professor R. A. Schapery. The intent of this subcontract was to (1) support the theoretical and experimental efforts being conducted at Aerojet, (2) provide an independent laboratory and technical staff to test and verify constitutive assumptions, (3) study the relation between Farris' non-fading memory constitutive theory and Schapery's thermodynamic theory, and (4) compare the relation, if any, between Farris' model for the Mullins' effect and Knauss' theory for the influence of microstructural cracks on the mechanical response of propellants.

The work performed at Texas A&M not only provided support for the work and representations used at Aerojet but recommended alternate inverse representations using  $L_p$  norms in stress rather than strain. In particular, the energy approach used by Schapery was instrumental in suggesting simplified three dimensional representations using only two strain invariants, the dilatation and the octahedral shear strain and bringing out the coupled dependency of dilatation and mean pressure on octahedral shear strain.

APPENDIX A

STUDIES ON THE NONLINEAR VISCOELASTIC  
BEHAVIOR OF SOLID PROPELLANT

Final Report from  
Texas A&M University

By  
R. A. Schapery

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STUDIES ON THE NONLINEAR VISCOELASTIC  
BEHAVIOR OF SOLID PROPELLANT

R. A. Schapery

May 1973

I. INTRODUCTION AND SUMMARY

The state-of-the-art of nonlinear viscoelastic characterization of solid propellant existing just prior to the start of this investigation was reviewed in [1]. Although some promising models had been proposed, such as Farris' representation of microstructural damage [2], little experimental verification existed for propellant with vacuole dilatation. The present study was undertaken in cooperation with Aerojet Solid Propulsion Company in order to develop mathematical models for characterizing solid propellant under realistic states of strain. Emphasis of the study at Texas A&M University was on the development of simple constitutive equations for propellant having very large amounts of vacuole dilatation and on the application of viscoelastic fracture mechanics to constitutive theory.

In Section II, constitutive equations based on thermodynamic principles are examined for elastic and viscoelastic media with microstructural damage. These equations provide the framework for establishing some special cases which apply to solid propellant. The role of fracture

mechanics in constitutive theory is brought out using the theory developed in [3].

The experimental investigations described in Section III cover uniaxial, strip biaxial, and poker chip tests. Dilatation was measured in all three modes; a dilatometer was used for the former two tests and changes in circumference were monitored to obtain dilatation in the poker chip test [4]. The strip biaxial and uniaxial data were found to support the proposed constitutive model. Poker chip test results turned out to be of rather limited quantitative use, especially with compressive loading, because of the strong nonlinearities exhibited by the propellant.

## II. THEORETICAL INVESTIGATIONS

Three-dimensional constitutive equations for nonlinear media with microstructural damage are developed in this section. Results from thermodynamic theory are used to establish the general form of the equations, while possible measures of damage are examined in the light of viscoelastic fracture mechanics theory. As a means of clearly bringing out certain physical aspects of the problem we first derive equations for damaged elastic media. Viscoelastic equations are then developed. In order to provide a sufficiently general theory for incorporating physical models of microstructural damage and to be able to examine the relative merits of different specific representations, we examine both the case in which stresses are expressed as functions of strains and in which strains are functions of stresses.

For simplicity of notation, infinitesimal strain theory is used in the theoretical development of constitutive equations. However, at the end of Section II we show how the results can be immediately extended to finite strain theory by simply making a change in the notation.

### A. Constitutive Equations for Elastic Media with Microstructural Damage

Introductory comments: Consider first a nonlinear elastic body with an arbitrary distribution of cracks with fixed length. Derivation of the overall stress-strain equations can be accomplished by following the same steps used for uncracked bodies. Specifically, by combining the First and Second Laws of Thermodynamics, with strains and temperature being the independent state variables, there results for isothermal processes [ 5 ]:

$$\sigma_{ij} = \frac{\partial F_e}{\partial \epsilon_{ij}} \quad (1)$$

where  $F_e$  is the Helmholtz free energy/initial volume ("strain energy"). It is a function of the strains,  $\epsilon_{ij}$ , temperature,  $T$ , and a set of parameters ( $\beta_k$ , say) which are needed to define the geometry (size, shape, orientation, location) of all cracks. The inverse strain-stress equation for isothermal processes likewise can be derived from thermodynamics by taking stresses and temperature as the independent variables [ 5 ]:

$$\epsilon_{ij} = \frac{\partial F_s}{\partial \sigma_{ij}} \quad (2)$$

where  $-F_s$  is the Gibbs free energy per unit initial volume ("complementary strain energy"). The energy  $F_s$  is, in general, a function of the stresses,  $\sigma_{ij}$ , temperature,  $T$ , and the crack parameters  $\beta_k$ .

Berry [ 6 ] has used the one-dimensional form of Eq. (2) to derive the overall Young's modulus,  $E_e$ , of a large linear elastic sheet under uniformly applied tensile stress,  $\sigma_{11}$ , and with one crack perpendicular to the external load. He obtained:

$$\epsilon_{11} = \frac{\partial F_s}{\partial \sigma_{11}} = \frac{\sigma_{11}}{E} \left( 1 + \frac{2\pi a^2}{A} \right) \quad (3a)$$

where  $E$  is the uncracked Young's modulus,  $2a$  is the constant crack length, and  $A$  = sheet length x width. Thus,

$$E_e \equiv \frac{\sigma_{11}}{\epsilon_{11}} = \left( 1 + \frac{2\pi a^2}{A} \right)^{-1} E \quad (3b)$$

If there are  $N$  noninteracting cracks of length  $2a_k$ , instead of one crack, then  $a^2$  in Eq. (3b) is simply replaced by  $\sum_{k=1}^N a_k^2$  [ 7 ]; viz.

$$E_e = (1 + \frac{2\pi}{A} \sum_{K=1}^N a_K^2)^{-1} E \quad (3c)$$

Equations (1) - (3) are obviously valid for moving cracks in an elastic body as long as the velocities are small enough for kinetic energy to be negligible. With this case one must still perform the differentiation in Eqs. (1) and (2) with the parameters  $\beta_K$  (e.g.  $a_K$ ) held constant.

Predictions of time-dependent crack lengths and more realistic overall properties will be taken up in a later subsection. For now we shall assume the instantaneous values of  $\beta_K$  are known.

Equations for isotropic media with strains as the independent variables: Let us return to Eq. (1) and assume that it is valid regardless of the types of damage (e.g., submicroscopic polymer chain failure, binder cracks, and dewetting) which are characterized by the parameters  $\beta_K$ . For notational simplicity, explicit dependence of free energy on  $T$  and  $\beta_K$  will not be shown; but this dependence is to be assumed unless stated otherwise. Also, as noted previously, the partial derivatives with respect to strain are taken while holding damage (viz.  $\beta_K$ ) constant. Furthermore, we will assume that the body, with or without damage, is statistically homogeneous and isotropic. (The body is defined to be statistically isotropic if, after the external loads are removed, there are no preferred directions; the response to a new set of loads will be independent of the material's orientation. If, for example, all of the cracks in a body are parallel, it is not statistically isotropic; if, however, cracks and other flaws are sufficiently random in their orientation isotropy can be assumed.)

Under the above assumptions, the free energy will depend on strain at most through any three independent invariants of the strain tensor.

If, for example, we use the three invariants

$$\begin{aligned} I_1 &\equiv \epsilon_{ii} \\ I_2 &\equiv \epsilon_{ij} \epsilon_{ij} \\ I_3 &\equiv \epsilon_{ij} \epsilon_{jm} \epsilon_{mi} \end{aligned} \quad (4)$$

where repeated indices imply summation over the range 1, 2, 3, then Eqs. (1) and (4), together with the use of the chain rule and the assumption  $F_e = F_e(I_1, I_2, I_3)$ , yield (where  $\delta_{ij}$  is the Kronecker delta),

$$\sigma_{ij} = \frac{\partial F_e}{\partial I_1} \delta_{ij} + 2 \frac{\partial F_e}{\partial I_2} \epsilon_{ij} + 3 \frac{\partial F_e}{\partial I_3} \epsilon_{im} \epsilon_{mj} \quad (5)$$

The damage parameters  $\beta_K$ , which are implicitly included in  $F_e$ , may depend on the history of the invariants (and their current values), but not directly on the individual components of the strain tensor.

For physical reasons, it is often desirable to use instead the invariant  $I_1$  and the two strain-deviator invariants:

$$\begin{aligned} \tilde{I}_2 &\equiv e_{ij} e_{ij} \\ \tilde{I}_3 &\equiv e_{ij} e_{jm} e_{mi} \end{aligned} \quad (6)$$

where  $e_{ij}$  are the deviatoric strains,

$$e_{ij} \equiv \epsilon_{ij} - \frac{1}{3} \delta_{ij} I_1 \quad (7)$$

By substituting Eq. (7) into (6) we find

$$\begin{aligned} \tilde{I}_2 &= I_2 - \frac{1}{3} I_1^2 \\ \tilde{I}_3 &= I_3 - I_1 I_2 + \frac{2}{9} I_1^3 \end{aligned} \quad (8)$$

Equation (5) can be transformed to the deviator strains by using definition (7) and by applying the chain rule to the derivatives in (5); with  $F_e = F_e(I_1, \tilde{I}_2, \tilde{I}_3)$  we find

$$s_{ij} = - \frac{\partial F_e}{\partial \tilde{I}_3} \tilde{I}_2 \delta_{ij} - \frac{\partial F_e}{\partial \tilde{I}_2} e_{ij} + 3 \frac{\partial F_e}{\partial \tilde{I}_3} e_{im} e_{mj} \quad (9)$$

and

$$\frac{\theta}{3} = \frac{\partial F_e}{\partial I_1} \quad (10)$$

where  $s_{ij}$  are the deviatoric stresses,

$$s_{ij} \equiv \sigma_{ij} - \frac{1}{3} \delta_{ij} \theta \quad (11)$$

and  $\theta$  is the dilatational stress,

$$\theta \equiv \sigma_{11} \quad (12)$$

Note that when we set  $i = j$  in Eq. (9) and sum the three equations ( $j = 1, 2, 3$ ), the resulting equation is identically zero. Therefore, Eq. (9) defines five, rather than six, independent equations. These five equations, together with the dilatational Eq. (10), form a set which is equivalent to the set of six equations defined by Eq. (5). However, they are now separated into relations which express distortion, Eq. (9), and dilatation, Eq. (10).

For many metals and polymers (with or without filler particles), it is often possible to neglect the dependence of mechanical properties on  $\tilde{I}_3$  [8]; this simplification will be used in all of the following discussion as present indications are that it is valid for solid propellant. Thus, from Eq. (9) with  $F_e = F_e(I_1, \tilde{I}_2)$ :

$$s_{ij} = 2 \frac{\partial F}{\partial \tilde{I}_2} e_{ij} \quad (13)$$

while the form of dilatational Eq. (10) is unchanged.

An important point is that if dependence on  $\tilde{I}_3$  is not neglected, the deviatoric stresses in Eq. (9) are linear with respect to the square of the strain tensor, i.e.  $e_{in} e_{mj}$ . This dependence implies the deviatoric stress tensor is definitely not a homogeneous function to degree one. On the other hand, without  $\tilde{I}_3$ , Eq. (13) shows that it is at least possible (but not necessary) to select  $F_e$  such that the stress tensor satisfies this homogeneity condition.

An elastic free energy function for propellant: In this subsection we shall propose a specific free energy function which will be shown to predict actual nonlinear behavior of dewetted propellant. Specifically, we assume

$$F_e = \int_0^{I_T} K_1 I_T dI_T + \int_0^{\tilde{I}_2} G_2 d\tilde{I}_2 + N_1 N_2 \quad (14a)$$

where

$$I_T \equiv I_1 - 3\alpha\Delta T \quad (14b)$$

and the term  $3\alpha\Delta T$  is the volumetric thermal expansion due to temperature change  $\Delta T$ . Also,

$$K_1 = K_1(I_T) \quad , \quad G_2 = G_2(\tilde{I}_2)$$

$$N_1 = N_1(I_T) \quad , \quad N_2 = N_2(\tilde{I}_2)$$

are four nonlinear material property functions, each of which depends on only one invariant.

Substitute Eq. (14) into (10) and (13); thus

$$\frac{\theta}{3} = K_1 I_T + \frac{dN_1}{d\tilde{I}_1} N_2 \quad (15a)$$

$$s_{ij} = 2(G_2 + N_1 \frac{dN_2}{d\tilde{I}_2}) e_{ij} \quad (15b)$$

In the linear range of behavior, these equations must reduce to

$$\frac{\theta}{3} = K_e I_T \quad (16a)$$

$$s_{ij} = 2 G_e e_{ij} \quad (16b)$$

where  $K_e$  and  $G_e$  are the linear elastic bulk and shear moduli, respectively. Hence,  $K_1$  and  $G_2$  can be interpreted as the nonlinear generalizations of  $K_e$  and  $G_e$ , while  $N_1$  and  $N_2$  produce coupling between dilatational and shear phenomena. The product  $N_1 N_2$  must be selected such that, at small strains, it is at least of third order in the strains in order that the proper linear limiting case, Eq. (16), is obtained.

Let us now go one step further and assume

$$\begin{aligned} K_1 &= K_e, & G_2 &= G_e \\ N_1 &= K_e I_T \end{aligned} \quad (17)$$

and

$$\begin{aligned} N_2 &= 0 & \text{for } \tilde{I}_2 < b^2 \\ N_2 &= -a(\sqrt{\tilde{I}_2} - b) & \text{for } \tilde{I}_2 \geq b^2 \end{aligned} \quad (18)$$

where  $a$  and  $b$  are non-negative quantities.\* Substitution of Eqs.

(17) and (18) into (15) yields, for  $\tilde{I}_2 \geq b^2$ :

$$\frac{\theta}{3} = K_e [I_T - a(\sqrt{\tilde{I}_2} - b)] \quad (19a)$$

---

\*If  $b = 0$ , then the free energy function will be positive definite if and only if

$$a < \sqrt{2G_e/K_e}$$

$$s_{ij} = 2[G_e - \frac{aK_e I_T}{2\sqrt{\tilde{I}_2}}] e_{ij} \quad (19b)$$

while the linear relations (16) apply for  $\tilde{I}_2 < b^2$ .

It is of interest to examine Eq. (19) in some detail as these relations turn out to agree with a large amount of propellant data. First, observe that if  $G_e$ ,  $K_e$ , and  $a$  depend at most on constant damage parameters  $\beta_K$  and/or are homogeneous to degree zero in the invariants (through  $\beta_K$ ), then the deviatoric constitutive Eq. (19b) is homogeneous to degree one, and, in this regard, it agrees with Farris' observations [9]. However, the dilatational Eq. (19a) is not homogeneous to degree one unless (i)  $\tilde{I}_2 < b^2$  and  $K_e$  depends on  $\beta_K$  as noted above or (ii)  $\tilde{I}_2 \gg b^2$  and  $K_e$  and  $a$  both depend on  $\beta_K$  as noted above.

If the dilatational stress  $\theta$  is either known or is negligible, Eq. (19a) enables dilatation to be easily predicted; viz., for  $\tilde{I}_2 \geq b^2$ :

$$I_T \equiv I_1 - 3\alpha\Delta T = \frac{\theta}{3K_e} + a(\sqrt{\tilde{I}_2} - b) \quad (20)$$

The significance of this result in predicting dilatation in three common tests will be discussed in Section II-D.

Consider the simple shear test ( $\epsilon_{12} \neq 0$ ) in which  $\Delta T = 0$  and the propellant is constrained such that all normal strains vanish, which implies  $I_T \equiv 0$ . Equation (19a) yields, for  $\sqrt{\tilde{I}_2} = \sqrt{2} |\epsilon_{12}| \geq b$ ,

$$\frac{\theta}{3} = -K_e a(\sqrt{2} |\epsilon_{12}| - b) \quad (21)$$

Also, Eq. (19b) yields  $\sigma_{11} = \sigma_{22} = \sigma_{33}$ , and predicts that the effective shear modulus is  $G_e$ . Thus, the shear strain produces compressive normal stresses, which is consistent with experimental results [10]. Moreover, if the propellant is permitted to expand during shearing, Eq. (19b) predicts that the effective shear modulus will be less than that for no dilatation; this result, again, is consistent with propellant data [10].

Let us now return to Eq. (19b) and specialize it to uniaxial loading. Assuming  $\epsilon_{11} \gg |I_T|$ , we find

$$\sigma_{11} = 3 G_e \epsilon_{11} \left[ 1 - \beta \frac{I_T}{\epsilon_{11}} \right] \quad (22)$$

where

$$\beta = \frac{aK_e}{\sqrt{6} G_e} \quad (23)$$

As long as

$$1 - \beta \frac{I_1}{\epsilon_{11}} \approx e^{-\beta I_1 / \epsilon_{11}} \quad (24)$$

predicted stress (22) is the same as that reported by Farris [11], where  $\beta \approx 2 - 3$ .

We have assumed the quantities  $K_e$ ,  $G_e$ ,  $a$ , and  $b$  are constant insofar as the comparison with experimental data was concerned. The influence of damage parameters  $\beta_K$  on these quantities will be discussed in Section II-E.

It should be pointed out that the relations in Eq. (15), instead of those in Eq. (19), may be needed to characterize propellant subjected to moderate and high pressures. Alternatively, use of the method described in Section II-F together with Eq. (19) may prove to be better.

Equations for isotropic media with stresses as the independent variables: Constitutive equations corresponding to the isotropic version of Eq. (2) are completely analogous to those given in terms of strains. We introduce the dilatational stress invariant

$$\theta \equiv \sigma_{11} \quad (25a)$$

and the two deviatoric stress invariants

$$\tilde{J}_2 = s_{ij} s_{ij} \quad (25b)$$

$$\tilde{J}_3 = s_{ij} s_{jm} s_{mi} \quad (25c)$$

The deviatoric strains are found to be

$$e_{ij} = - \frac{\partial F}{\partial \tilde{J}_3} \tilde{J}_2 \delta_{ij} + 2 \frac{\partial F}{\partial \tilde{J}_2} s_{ij} + 3 \frac{\partial F}{\partial \tilde{J}_3} s_{im} s_{mj} \quad (26)$$

and the dilatational strain  $I_1$  is

$$\frac{I_1}{3} = \frac{\partial F}{\partial \theta} \quad (27)$$

If  $F_s$  is independent of the third stress invariant  $\tilde{J}_3$ , then Eq. (26) becomes simply

$$e_{ij} = 2 \frac{\partial F_s}{\partial \tilde{J}_2} s_{ij} \quad (28)$$

#### B. Constitutive Equations for Viscoelastic Media with Microstructural Damage

Equations for isotropic media with strains as the independent variables: The above considerations can be generalized to include viscoelastic behavior by drawing upon the irreversible thermodynamic theory in [12]. As before, we will assume that the dependence of material properties on  $\tilde{I}_3$  can be neglected. Furthermore, the strain measures  $q_1, \dots, q_6$ , in [12]

will be assumed as follows:

$$\begin{aligned} q_1 &= \phi + \epsilon_{11} & q_4 &= \epsilon_{12} \\ q_2 &= \phi + \epsilon_{22} & q_5 &= \epsilon_{23} \\ q_3 &= \phi + \epsilon_{33} & q_6 &= \epsilon_{13} \end{aligned} \quad (29)$$

where  $\phi = \phi(I_T, \tilde{I}_2)$  is a material property which is assumed to vanish in the absence of vacuole dilatation; at small strains, this function must be at least of second order in the strains in order for the measures of strain to reduce to the strains in the linear range of behavior. The significance of  $\phi$  will be seen by examining the resulting constitutive equations.

The use of Eq. (29) in the theory in [12] yields, after much rearrangement,

$$\frac{\theta}{3} = \frac{\partial F}{\partial I_T} e + a_F \frac{\partial q}{\partial I_T} \int_0^t \Delta K(\psi - \psi') \frac{dq}{d\tau} d\tau \quad (30a)$$

$$\begin{aligned} s_{ij} &= 2 \frac{\partial F}{\partial \tilde{I}_2} e_{ij} + 2 a_F \int_0^t \Delta G(\psi - \psi') \frac{de_{ij}}{d\tau} d\tau \\ &+ 2 a_F \frac{\partial q}{\partial \tilde{I}_2} e_{ij} \int_0^t \Delta K(\psi - \psi') \frac{dq}{d\tau} d\tau \end{aligned} \quad (30b)$$

where

$$q = q(I_T, \tilde{I}_2) \equiv 3\phi + I_T \quad (31)$$

is the nonlinear dilatational strain measure which may be a function of both  $I_T$  and  $\tilde{I}_2$ . Also,  $\Delta G$  and  $\Delta K$  in these relations are the LVE transient components of the shear and bulk relaxation moduli, respectively. In general, there may be four different nonlinear material property functions

in Eq. (30); viz.,  $F_e$ ,  $a_F$ ,  $q$  (or  $\phi$ ), and  $a_e$ , where  $a_e$  appears in the definition of reduced time  $\psi$ ,

$$\psi = \psi(t) \equiv \int_c^t dt/a_e ; \psi' \equiv \psi(\tau) ; a_e = a_e(I_T, \tilde{I}_2, T) \quad (32)$$

The term in Eq. (30b) involving  $\Delta K$  gives rise to dependence of deviatoric stress on volume-change history, even when the deviatoric strain is constant.

These same equations could have been derived more directly from the underlying thermodynamic theory, Eq. (19) in [12], without making use of the constitutive equations in [12] in terms of strains  $e_{ij}$  and stresses  $\sigma_{ij}$ . This alternative approach would consist of assuming that

$$q_1 = e_{11}, \dots, q_6 = e_{13} \quad (33a)$$

and

$$q_7 \equiv q = q(I_T, \tilde{I}_2) \quad (33b)$$

where all seven  $q_i$  are treated as independent state variables. The virtual work  $\delta W$ , which is used to derive the constitutive equations, is written in the form,

$$\delta W = s_{ij} \delta e_{ij} + \frac{1}{3} \theta \delta I_T + \lambda \delta_{ij} \delta e_{ij} = \sum_{m=1}^7 Q_m \delta q_m \quad (34)$$

It is to be noted that  $\delta_{ij} e_{ij} = e_{ii} \equiv 0$ , and therefore out of the six  $e_{ij}$ , only five are actually independent; however, all six can be treated as independent quantities in the virtual work condition (34) as long as the term  $\lambda \delta e_{ii}$  is added to the equation (where  $\lambda$  is a Lagrange multiplier).

The main point we want to make here is that constitutive equations

(30) can be viewed as being based on the assumption that the thermodynamic measures of deviatoric strain,  $q_1, \dots, q_6$ , are equal to the deviatoric strains themselves, while the thermodynamic measure of dilatation,  $q_7$ , is a function of the actual dilatation,  $I_T$ , and the deviatoric strains (through  $\tilde{I}_2$ ).

The present constitutive theory (30) can be simplified even further by assuming that when all strains are constant in time (generalized relaxation test) the form of the constitutive nonlinearity is independent of time.

For constant strains applied at  $t = 0$ , and using the relations

$$\Delta K(\psi) \equiv K(\psi) - K_e \quad (35a)$$

$$\Delta G(\psi) \equiv G(\psi) - G_e \quad (35b)$$

where

$$K_e \equiv K(\infty) \text{ and } G_e \equiv G(\infty) ,$$

we find that Eq. (30) reduces to

$$\frac{\theta}{3} = \left[ \frac{\partial F_e}{\partial I_T} - \frac{a_F}{2} \frac{\partial q^2}{\partial I_T} K_e \right] + \frac{a_F}{2} \frac{\partial q^2}{\partial I_T} K(\psi) \quad (36a)$$

$$\begin{aligned} s_{ij} = & \left[ 2 \frac{\partial F_e}{\partial \tilde{I}_2} - 2a_F G_e - a_F \frac{\partial q^2}{\partial \tilde{I}_2} K_e \right] e_{ij} + 2a_F G(\psi) e_{ij} \\ & + a_F \frac{\partial q^2}{\partial \tilde{I}_2} K(\psi) e_{ij} \end{aligned} \quad (36b)$$

The nonlinear form of Eq. (36) at short times,  $\psi \approx 0$ , will be different from that long time,  $\psi \rightarrow \infty$ , unless the sums in square brackets vanish; viz.,

$$\frac{\partial F_e}{\partial I_T} = \frac{a_F}{2} \frac{\partial q^2}{\partial I_T} K_e \quad (37)$$

$$2 \frac{\partial F_e}{\partial \tilde{I}_2} = 2a_F G_e + a_F \frac{\partial q^2}{\partial \tilde{I}_2} K_e \quad (38)$$

Define a new function  $g$ ,

$$g \equiv q^2 + 2 \frac{G_e}{K_e} \tilde{I}_2 \quad (39)$$

and then combine Eqs. (37) and (38) to obtain a single equation for  $g$ :

$$\frac{\partial g}{\partial I_T} \frac{\partial F_e}{\partial \tilde{I}_2} - \frac{\partial g}{\partial \tilde{I}_2} \frac{\partial F_e}{\partial I_T} = 0 \quad (40)$$

This equation is solved by a standard method [13] to yield  $g = g(F_e)$ . Namely,  $g$  is an (almost) arbitrary function of the single quantity,  $F_e$ ; in the linear range of behavior  $q$  must reduce to  $I_T$ , which implies  $g$  must be such that

$$g = \frac{2}{K_e} F_e \quad \text{when} \quad |F_e| \ll 1 \quad (41)$$

which is the only restriction on the function  $g(F_e)$ . From Eq. (39),

$$q^2 = g(F_e) - 2 \frac{G_e}{K_e} \tilde{I}_2 \quad (42a)$$

and from Eq. (37),

$$a_F = - \frac{2}{K_e (dg/dF_e)} \quad (42b)$$

and Eq. (36) for constant strains becomes

$$\frac{\theta}{3} = \frac{\partial F_e}{\partial I_T} \frac{K(\psi)}{K_e} \quad (43a)$$

$$s_{ij} = 2a_F [G(\psi) - G_e \frac{K(\psi)}{K_e} + \frac{1}{a_F} \frac{\partial F_e}{\partial \tilde{I}_2} \frac{K(\psi)}{K_e}] e_{ij} \quad (43b)$$

and Eq. (30) for transient strains becomes

$$\frac{\theta}{3} = a_F \frac{\partial q}{\partial \tilde{I}_T} \int_0^t K(\psi - \psi') \frac{dq}{d\tau} d\tau \quad (44a)$$

$$s_{ij} = 2a_F \left[ \int_0^t G(\psi - \psi') \frac{de_{ij}}{d\tau} d\tau \right. \quad (44b)$$

$$\left. + \frac{\partial q}{\partial \tilde{I}_2} e_{ij} \int_0^t K(\psi - \psi') \frac{dq}{d\tau} d\tau \right]$$

where, in Eqs. (43) and (44),  $a_F$  and  $q$  are to be expressed in terms of the auxiliary function  $g$ , which, in turn, is an arbitrary function of  $F_e$  (except for condition (41)).

Thus, the constitutive equations now contain three independent material property functions:  $F_e$ ,  $g$ , and  $a_e$ , each of which may depend on a set of damage parameters,  $\beta_K$ .

As one further simplification, assume

$$K(\psi) = A'G(\psi) \quad (45)$$

where  $A'$  is a constant; this behavior was reported in [4] for propellant, as determined from poker-chip tests. Relaxation relations (43) become

$$\frac{\theta}{3} = \frac{\partial F_e}{\partial \tilde{I}_T} \frac{G(\psi)}{G_e} \quad (46a)$$

$$s_{ij} = 2 \frac{\partial F_e}{\partial \tilde{I}_2} \frac{G(\psi)}{G_e} e_{ij} \quad (46b)$$

When Eq. (44) is specialized to a uniaxial relaxation test, and

condition (45) is used, we find that the dilatation is independent of time; this behavior for one propellant was reported by Farris [14]. However, for the PBAN propellant studied on this program, as well as for an 82 wt% CTPB propellant studied at the Naval Ordnance Station [15], some change in volume occurred during relaxation. Equation (44) is sufficiently general to predict such behavior, as long as condition (45) is not invoked.

Finally, attention is called to the fact that Eq. (44) is capable of predicting a history-dependent pressure build-up due to shear straining, even when  $I_T = 0$ . This behavior is a result of the dependence of  $q$  on  $\tilde{I}_2$ .

Equations for isotropic media with stresses as the independent variables: From the theory in [16] we deduce a set of constitutive equations which are similar to those in Eq. (30); viz.

$$\frac{I_1}{3} = \frac{\partial F_s}{\partial \theta} + \frac{1}{9} \frac{\partial Q}{\partial \theta} \int_0^t \Delta B(\psi - \psi') \frac{d(Q/a_G)}{d\tau} d\tau \quad (47a)$$

$$e_{ij} = 2 \frac{\partial F_s}{\partial \tilde{J}_2} s_{ij} + \frac{1}{2} \int_0^t \Delta J(\psi - \psi') \frac{d(s_{ij}/a_G)}{d\tau} d\tau \\ + 2 \frac{\partial Q}{\partial \tilde{J}_2} s_{ij} \int_0^t \Delta B(\psi - \psi') \frac{d(Q/a_G)}{d\tau} d\tau \quad (47b)$$

where  $F_s$ ,  $Q$ , and  $a_G$  are material functions of the invariants  $\theta$  and  $\tilde{J}_2$ . Also  $\Delta B$  and  $\Delta J$  are the transient components of the linear viscoelastic creep compliances in bulk and simple shear, respectively. Special forms of Eq. (47) analogous to those in Eq. (44) can be deduced; but, we shall

not pursue these cases here.

### C. On Constitutive Equations which are Homogeneous to Degree One

This subsection is concerned with the following questions: (1) given constitutive equations in which the stress tensor  $\sigma_{ij}$  is expressed as a homogeneous functional to degree one in the strain tensor  $\epsilon_{ij}$ , and assuming unique inverse relations exist (i.e., strain tensor is a unique functional of the stress tensor) are they homogeneous to degree one?; and (2) under what conditions do inverse relations exist?

We shall prove first that the answer to question (1) is "yes" and then state a general criterion as the answer to question (2).

Write the given functional constitutive equations as

$$\sigma_{ij} = g_{ij}(\epsilon_{kl}) \quad (48)$$

where

$$g_{ij}(a\epsilon_{kl}) = ag_{ij}(\epsilon_{kl}) \quad (49)$$

with  $a$  = constant scalar. We assume unique inverse relations exist, i.e.,

$$\epsilon_{ij} = f_{ij}(\sigma_{kl}) \quad (50)$$

By definition of  $f_{ij}$ ,

$$\sigma_{ij} = g_{ij}[f_{kl}(\sigma_{mn})] \quad (51)$$

It will now be proved that  $f_{ij}$  is homogeneous to degree one in the stresses; viz.

$$f_{ij}(c\sigma_{kl}) = cf_{ij}(\sigma_{kl}) \quad (52)$$

where  $c$  = constant scalar. Write Eq. (51) for stresses  $\sigma'_{ij}$ ,

$$\sigma'_{ij} = g_{ij}[f_{kl}(\sigma'_{mn})] \quad (53a)$$

where

$$\sigma_{ij} = c \sigma_{ij} \quad (53b)$$

Substitute (53b) into (53a),

$$\sigma_{ij} = \frac{1}{c} g_{ij} [f_{kl}(c\sigma_{mn})] \quad (54)$$

Upon using (49), with  $a = 1/c$ , we find

$$\sigma_{ij} = g_{ij} \left[ \frac{1}{c} f_{kl}(c\sigma_{mn}) \right] \quad (55)$$

In view of equations (51) and (55), and the uniqueness assumption (i.e., for a given stress tensor, there exists only one strain tensor), we observe,

$$\frac{1}{c} f_{kl}(c\sigma_{mn}) = f_{kl}(\sigma_{mn}) \quad (56a)$$

or

$$f_{kl}(c\sigma_{mn}) = c f_{kl}(\sigma_{mn}) \quad (56b)$$

which, according to equation (52), completes the proof.

Now, consider the question (2). If the quantities  $g_{ij}$ , Eq. (48), are algebraic we can use the well-known result from the theory of coordinate transformations that the inverse relations exist and are unique if [5]:

- i. The six functions  $g_{ij}$  are single-valued, continuous, and possess continuous  $g_{ij}$  first partial derivatives throughout the body of interest.
- ii. The Jacobian determinant,

$$J \equiv |\partial g_{ij} / \partial \epsilon_{kl}|, \text{ does not vanish at any point in the body.}$$

A simple example for which a unique inverse does not exist is the one-dimensional uniaxial case for which  $\sigma = \sigma(\epsilon)$  has a maximum point at

$\epsilon = \epsilon_m$ , say; for all strains  $\epsilon \geq \epsilon_m$ , a unique single-valued relation  $\epsilon = \epsilon(\sigma)$  does not exist.

In the actual case of interest,  $g_{ij}$  represents a set of six functionals; i.e., it depends on strain history. However, this set of functionals can be reduced to algebraic functions, which can then be subjected to the above stated conditions for invertability. This reduction is easily accomplished (in principle) by approximating the strain histories by piecewise linear or step functions of time. In this form the original functionals  $g_{ij}$  become algebraic functions of the constants defining the approximate strain histories. If, for example, we consider all six strains and let each strain history be represented by ten constants, there will be 60 x 60 terms in the Jacobian determinant.

In view of the last comment, a completely general study of invertability would be impractical. However, significant insight into the problem could be gained by examining simple situations, such as the stress-strain equations defining the behavior of a bar under confining pressure and uniaxial tension.

#### D. The Dilatational Constitutive Equation

Characterization of the effect of vacuole formation and growth on the relation between dilatational stress,  $\theta$ , and dilatational strain,  $L_T$ , is an important and very difficult part of the overall nonlinear viscoelastic characterization problem. In this section, the so-called dilatational constitutive equation is therefore singled-out for special study. Recall that some forms of this equation for the elastic case,

e.g. Eqs. (10) and (19a), and the viscoelastic case, e.g. Eqs. (30a) and (47a), have already been given.

We first define the vacuole dilatation  $I_V$  by the following equation:

$$I_V \equiv I_1 - 3\alpha\Delta T - \frac{\theta}{3K_e} = I_T - \frac{\theta}{3K_e} \quad (57)$$

where  $K_e$  = bulk modulus in the unstressed state; voids may exist in this state. (Note that, in the linear elastic range of behavior

$$I_1 = 3\alpha\Delta T + \frac{\theta}{3K_e} \quad (58)$$

and therefore  $I_V = 0$ .) Also by definition,  $I_V$  is never negative.

In general,  $I_V$  can be expressed as a function of the history of the three stress invariants and temperature or the three strain invariants and temperature. We chose the latter four scalars here, and write

$$I_V = F \{ I_T, \quad \tilde{I}_2, \quad \tilde{I}_3, \quad T \} \quad (59)$$

Now, substitute Eq. (57) for  $I_V$  and find

$$I_T = \frac{\theta}{3K_e} + F \{ I_T, \quad \tilde{I}_2, \quad \tilde{I}_3, \quad T \} \quad (60)$$

In order to obtain a form which is useful for application to experimental data we solve Eq. (60) for mechanical dilatation:

$$I_T = G \left\{ \frac{\theta}{3K_e}, \quad \tilde{I}_2, \quad \tilde{I}_3, \quad T \right\} \quad (61)$$

where  $G \{ \}$  is a function of the history of its arguments.

Let us now examine some special cases of Eq. (61). Assume first vacuole formation and growth depends only upon  $I_T$ ,  $T$ , and the maximum shear strain  $\epsilon_s$  (instead of  $\tilde{I}_2$  and  $\tilde{I}_3$  separately); the maximum shear

strain is given by

$$\epsilon_s = \frac{\epsilon_1 - \epsilon_3}{2} \quad (62)$$

where  $\epsilon_1$  and  $\epsilon_3$  are, by definition, the algebraically largest and smallest principal strains, respectively; note that  $\epsilon_s \geq 0$ . Equation (61) Becomes

$$I_T = G \left\{ \frac{\theta}{3K_e}, \epsilon_s, T \right\} \quad (63)$$

A special case of  $G$ , which turns out to fit the general form of Farris' uniaxial, constant strain-rate data [11] is the piecewise linear algebraic function

$$I_T = \begin{cases} \frac{\theta}{3K_e} & : \epsilon_s < b_s \\ \frac{\theta}{3K_e} + a_s(\epsilon_s - b_s) & : \epsilon_s \geq b_s ; (a_s, b_s) \geq 0 \end{cases} \quad (64)$$

where  $a_s$  and  $b_s$  may be functions of  $\theta$ ,  $T$ , and  $\dot{\epsilon}_s$ . It is seen that the material is idealized such that vacuoles do not form until the maximum shear strain,  $\epsilon_s$ , reaches  $b_s$ ; thus, large positive values of  $\theta$  are precluded.

Alternatively, we could, as in Section A, suppose that the constitutive function is independent of  $\tilde{I}_3$ . For easy reference we record here the special result derived earlier (see Eq. (20)):

$$I_T = \begin{cases} \frac{\theta}{3K_e} & : \tilde{I}_2 < b^2 \\ \frac{\theta}{3K_e} + a(\sqrt{\tilde{I}_2} - b) & : \tilde{I}_2 \geq b^2 \end{cases} \quad (65)$$

Equations (63) and (64) will be called the maximum shear strain

theory (MSS) while Eq. (61), without dependence on  $\bar{I}_3$ , and Eq. (65) will be called the octahedral shear strain theory (OSS) because this strain invariant is proportional to  $\sqrt{I_2}$ . We now examine the implications of Eq. (64) for the uniaxial, strip-biaxial, and double-lap simple shear tests.

Uniaxial test (MSS): For this test, with or without a confining pressure, the principal strains  $\epsilon_1$ ,  $\epsilon_2$ , and  $\epsilon_3$  are

$$\epsilon_1 = \epsilon_u = \text{applied axial strain} \quad (66a)$$

and

$$\epsilon_2 = \epsilon_3 \quad (66b)$$

The invariants  $I_1$  and  $\epsilon_s$  are

$$I_1 = \epsilon_u + 2\epsilon_3 \text{ and } \epsilon_s = (\epsilon_u - \epsilon_3)/2. \quad (67)$$

Substituting Eq. (66) into (64) and solving for  $\epsilon_3$  yields, for

$\epsilon_s \geq b_s$ :

$$\epsilon_3 = \frac{3\alpha\Delta T + \frac{\theta}{3K_e} - a_s b_s - (1 - \frac{a_s}{2}) \epsilon_u}{(2 + a_s/2)} \quad (68)$$

Also for  $\epsilon_s \geq b_s$ , the dilatation becomes

$$I_1 = 3\alpha\Delta T + \frac{\theta}{3K_e} + \frac{3\epsilon_s}{4+a_s} \left[ \epsilon_u - \frac{4b_s}{3} - \alpha\Delta T - \frac{\theta}{9K_e} \right] \quad (69)$$

When  $\epsilon_s < b_s$ , set  $a_s = 0$  to obtain the dilatation.

Note that the last term in Eq. (69) is the vacuole dilatation; viz,

$$I_v = \frac{3a_s}{4+a_s} \left[ \epsilon_u - \frac{4b_s}{3} - \alpha\Delta T - \frac{\theta}{9K_e} \right] \quad (70)$$

which applies when the condition

$$\epsilon_s = \frac{\epsilon_u - \epsilon_3}{2} \geq b_s \quad (71a)$$

is satisfied. Upon substitution of  $\epsilon_3$ , Eq. (68), into Eq. (71a) we find

$$\epsilon_u \geq \frac{4b_s}{3} + \alpha\Delta T + \frac{\theta}{9K_e} \quad (71b)$$

which is simply the requirement that the vacuole dilatation be non-negative.

Strip-biaxial test (MSS): The strip is assumed to be clamped in place at the reference temperature, for which  $\Delta T = 0$ . Further, the grips are assumed to be so rigid that the strain in the length direction,  $\epsilon_2$ , is essentially zero for all loading conditions. The principal strains are, therefore

$$\epsilon_1 \equiv \epsilon_b = \text{applied strain} \quad (72a)$$

$$\epsilon_2 = 0 \quad (72b)$$

$$\epsilon_3 = \text{thickness strain} \quad (72c)$$

The invariants are

$$I_1 = \epsilon_b + \epsilon_3, \quad \epsilon_s = \frac{\epsilon_b - \epsilon_3}{2} \quad (73)$$

The basic dilatational Eq. (64) yields for  $\epsilon_s \geq b_s$ :

$$\epsilon_3 = \frac{3\alpha\Delta T + \frac{\theta}{3K_e} - a_s b_s - (1 - \frac{a_s}{2}) \epsilon_b}{(1 + a_s/2)} \quad (74)$$

and

$$I_1 = 3\alpha\Delta T + \frac{\theta}{3K_e} + \frac{2a_s}{2+a_s} [\epsilon_b - b_s - \frac{3}{2}\alpha\Delta T - \frac{\theta}{6K_e}] \quad (75)$$

where the last term is the vacuole dilatation:

$$I_v = \frac{2a_s}{2 + a_s} [\epsilon_b - b_s - \frac{3}{2} \alpha \Delta T - \frac{\theta}{6K_e}] \quad (76)$$

which is valid when  $\epsilon_s \geq b_s$ ; i.e.

$$\epsilon_b \geq b_s + \frac{3}{2} \alpha \Delta T + \frac{\theta}{6K_e} \quad (77)$$

When Eq. (77) is not satisfied, the vacuole dilatation is given by Eq. (76) with  $a_s = 0$ .

Simple shear test (MSS): The specimen is assumed to be clamped in position at the reference temperature for which  $\Delta T = 0$ . It is also assumed that the outer two plates are rigidly fastened together and the specimen is thin with respect to the dimensions in the plane of shearing and is long in the direction of shearing. Under these assumptions, the specimen is in a state of simple shear in the plane of shearing. The principal strains are

$$\epsilon_1 = \gamma/2 \quad (78a)$$

$$\epsilon_2 = \text{thickness strain} \quad (78b)$$

$$\epsilon_3 = -\epsilon_1 = -\gamma/2 \quad (78c)$$

where

$\gamma$  = applied shear strain

= shear displacement/specimen dimension normal to displacement.

The invariants  $I_1$  and  $\epsilon_s$  become

$$I_1 = \epsilon_2 \quad \text{and} \quad \epsilon_s = \gamma/2 \quad (79)$$

We find the thickness strain (for  $\epsilon_s \geq b_s$ ) from Eq. (64):

$$\epsilon_2 = 3\alpha\Delta T + \frac{\theta}{3K_e} + a_s\left(\frac{Y}{2} - b_s\right) \quad (80)$$

and, in terms of the maximum principal strain,  $\epsilon_1$ :

$$I_1 = 3\alpha\Delta T + \frac{\theta}{3K_e} + a_s(\epsilon_1 - b_s) \quad (81)$$

where the vacuole dilatation is now

$$I_v = a_s(\epsilon_1 - b_s) \quad (82)$$

The condition  $\epsilon_s \geq b_s$  is the same as  $\epsilon_1 \geq b_s$ ; also, set  $a_s \equiv 0$  whenever  $\epsilon_1 < b_s$ .

Representation of vacuole dilatation in terms of strains due to externally applied loads (MSS): If after clamping, but prior to loading in a test machine, the specimens are subjected to a temperature change,  $\Delta T$ , and pressurization,  $p = -\theta/3$ , the strains in this state are:

$$\epsilon_u = \alpha\Delta T + \frac{\theta}{9K_e} = \alpha\Delta T - \frac{p}{3K_e} \quad (\text{uniaxial test}) \quad (83a)$$

$$\epsilon_b = \frac{3}{2} \alpha\Delta T + \frac{\theta}{6K_e} = \frac{3}{2} \alpha\Delta T - \frac{p}{2K_e} \quad (\text{biaxial test}) \quad (83b)$$

$$\epsilon_1 = 0 \quad (\text{shear test}) \quad (83c)$$

where, for the biaxial and shear tests, we have assumed  $\nu \approx \frac{1}{2}$ , which implies the three principal stresses under external pressure,  $p$ , are all approximately equal to  $-p$ .

If the specimens are now strained in the test machine, the principal strains  $\epsilon_{ue}$ ,  $\epsilon_{be}$ ,  $\epsilon_{se}$ , say, due to the externally applied load are equal

to the difference between  $\epsilon_u$ , and  $\epsilon_b$ , and  $\epsilon_1$  and the respective initial strains (83):

$$\epsilon_{ue} = \epsilon_u - \alpha \Delta T + \frac{P}{3K_e} \quad (\text{uniaxial test}) \quad (84a)$$

$$\epsilon_{be} = \epsilon_b - \frac{3}{2} \alpha \Delta T + \frac{P}{2K_e} \quad (\text{biaxial test}) \quad (84b)$$

$$\epsilon_{se} = \epsilon_1 \quad (\text{shear test}) \quad (84c)$$

Now,  $\theta$  for the uniaxial test is

$$\theta = -3p + \sigma_u \quad (85a)$$

and for the biaxial test

$$\theta = -3p + \frac{3\sigma_b}{2} \quad (85b)$$

where  $\sigma_u$  and  $\sigma_b$  are the stresses applied by the testing machine to the uniaxial and strip-biaxial specimens, respectively.

Upon substituting Eqs. (84) and (85) into Eqs. (70), (76), and (82) we find

$$I_v = \frac{3a_s}{4+a_s} \left[ \epsilon_{ue} - \frac{4}{3} b_s - \frac{\sigma_u}{9K_e} \right] \quad (\text{uniaxial test}) \quad (86a)$$

$$I_v = \frac{2a_s}{2+a_s} \left[ \epsilon_{be} - b_s - \frac{\sigma_b}{4K_e} \right] \quad (\text{biaxial test}) \quad (86b)$$

$$I_v = a_s (\epsilon_{se} - b_s) \quad (\text{shear test}) \quad (86c)$$

Recall that  $K_e$  is the bulk modulus in the unstressed state. Thus, the terms  $\sigma_u/9K_e$  and  $\sigma_b/4K_e$  are expected to be relatively small, and therefore will be neglected in the remainder of Section D. Analogous terms will be neglected in the OSS theory.

We now turn to the application of Eq. (65) to prediction of dilatation in the three tests. Essentially the same steps as in the MSS theory are followed in predicting vacuole dilatation from the OSS theory; consequently, we shall omit the details of the derivations. The strains  $\epsilon_{ue}$ ,  $\epsilon_{be}$ , and  $\epsilon_{se}$  are defined in the same way in both theories.

Uniaxial test (OSS): The vacuole dilatation is found to be

$$I_v = \frac{3a}{\sqrt{6} + a} (\epsilon_{ue} - \sqrt{\frac{2}{3}} b) \quad (87)$$

when  $\epsilon_{ue} \geq \sqrt{\frac{2}{3}} b$ ; for smaller strains set  $a \equiv 0$ .

Strip-biaxial test (OSS): The vacuole dilatation is not predicted to be piecewise linear for this test. Instead, for  $\epsilon_{be} \geq b/\sqrt{2}$  it is defined by the quadratic equation,

$$\left(\frac{1}{a^2} - \frac{2}{3}\right) I_v^2 + 2I_v \left(\frac{b}{a} + \epsilon_{be}\right) + (b^2 - 2\epsilon_{be}^2) = 0 \quad (88a)$$

with the positive root being

$$I_v = \frac{ab}{(1 - \frac{2a^2}{3})} \left[ -1 - \frac{a}{b} \epsilon_{be} + \sqrt{\frac{2}{3} a^2 + \frac{2a}{b} \epsilon_{be} + \left(2 - \frac{a^2}{3}\right) \frac{\epsilon_{be}^2}{b^2}} \right] \quad (88b)$$

Simple shear test (OSS): A quadratic relation is also found for the vacuole dilatation in the shear test:

$$\left(\frac{1}{a^2} - \frac{2}{3}\right) I_v^2 + 2 \frac{b}{a} I_v + b^2 - 2\epsilon_{se}^2 = 0 \quad (89a)$$

The positive root of this equation is

$$I_v = \frac{ab}{(1 - \frac{2a^2}{3})} \left[ -1 + \sqrt{\frac{2a^2}{3} + \left(2 - \frac{4}{3} a^2\right) \frac{\epsilon_{se}^2}{b^2}} \right] \quad (89b)$$

Comparison of MSS and OSS theories: Figures 1-3 illustrate vacuole dilatation predicted by Eqs. (86) and (87)-(89). The quantity  $a_u$

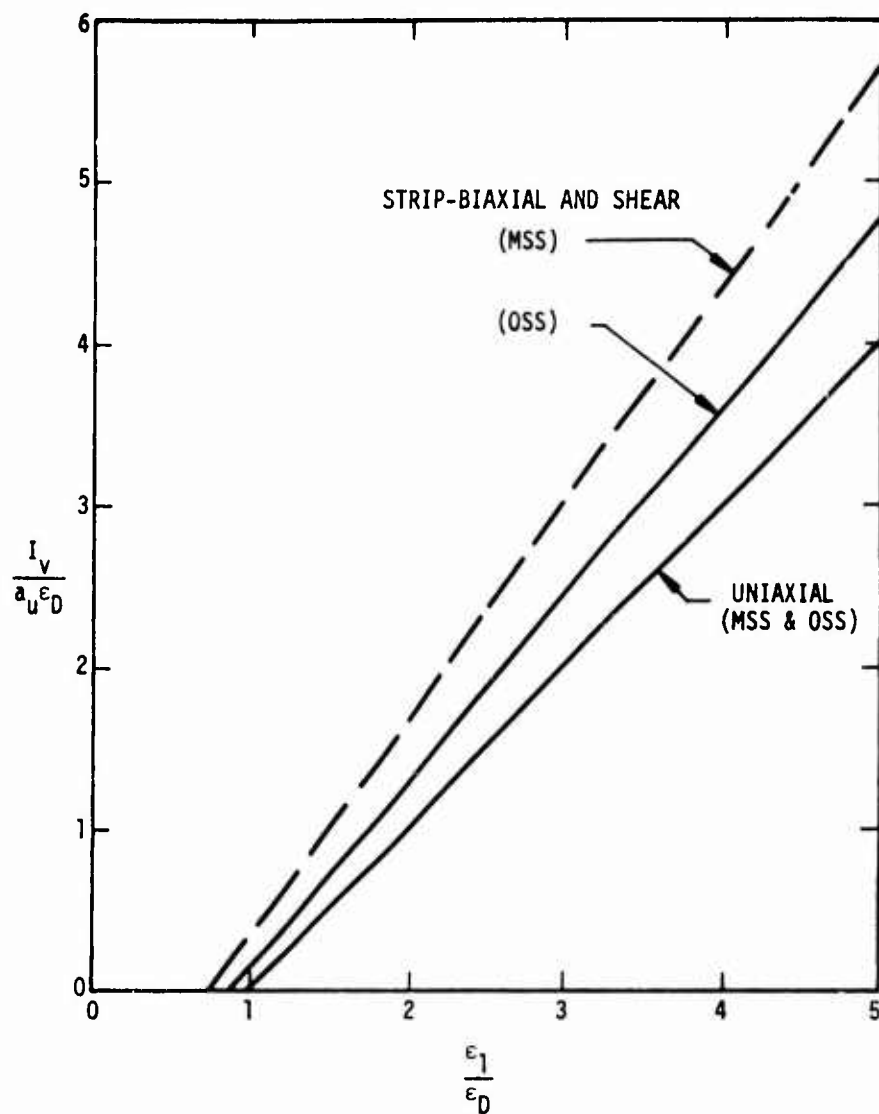


Figure 1. Comparison of Octahedral and Maximum Shear Strain Theories for  $a_u \ll 1$ .

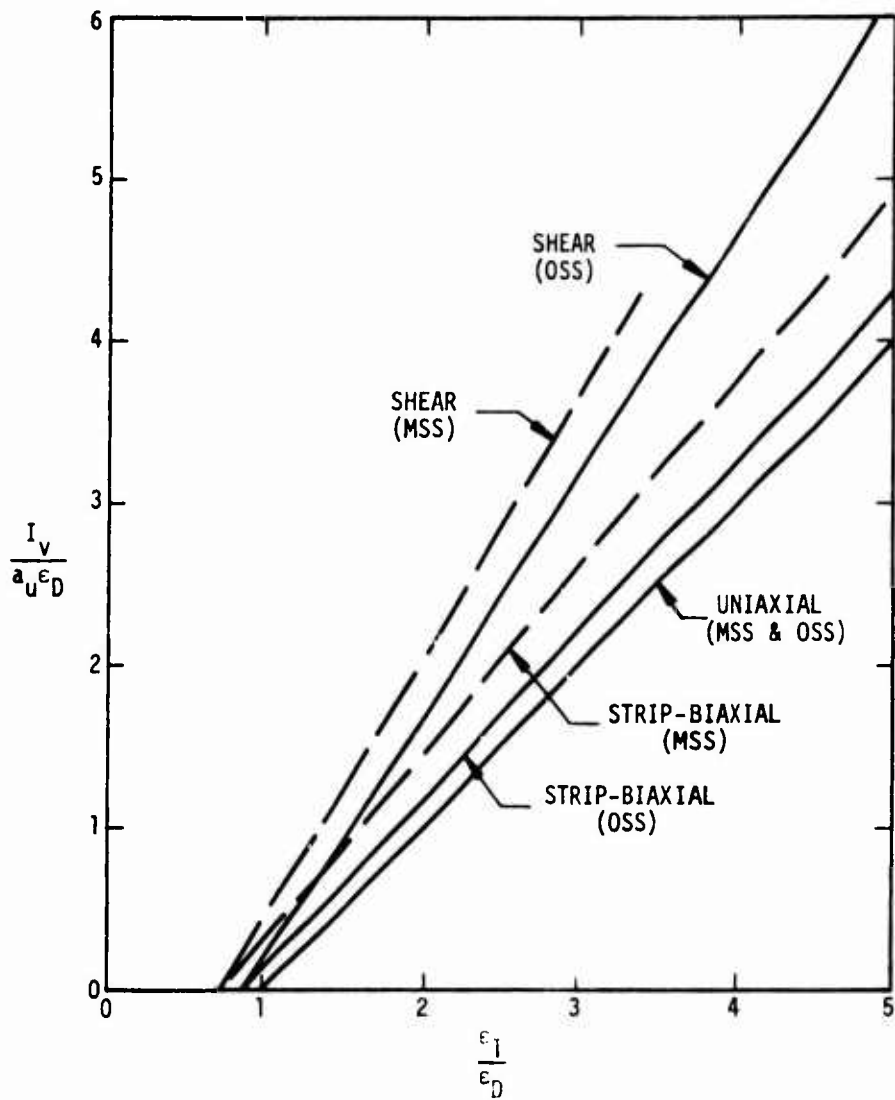


Figure 2. Comparison of Octahedral and Maximum Shear Strain Theories for  $a_u = 0.5$ .

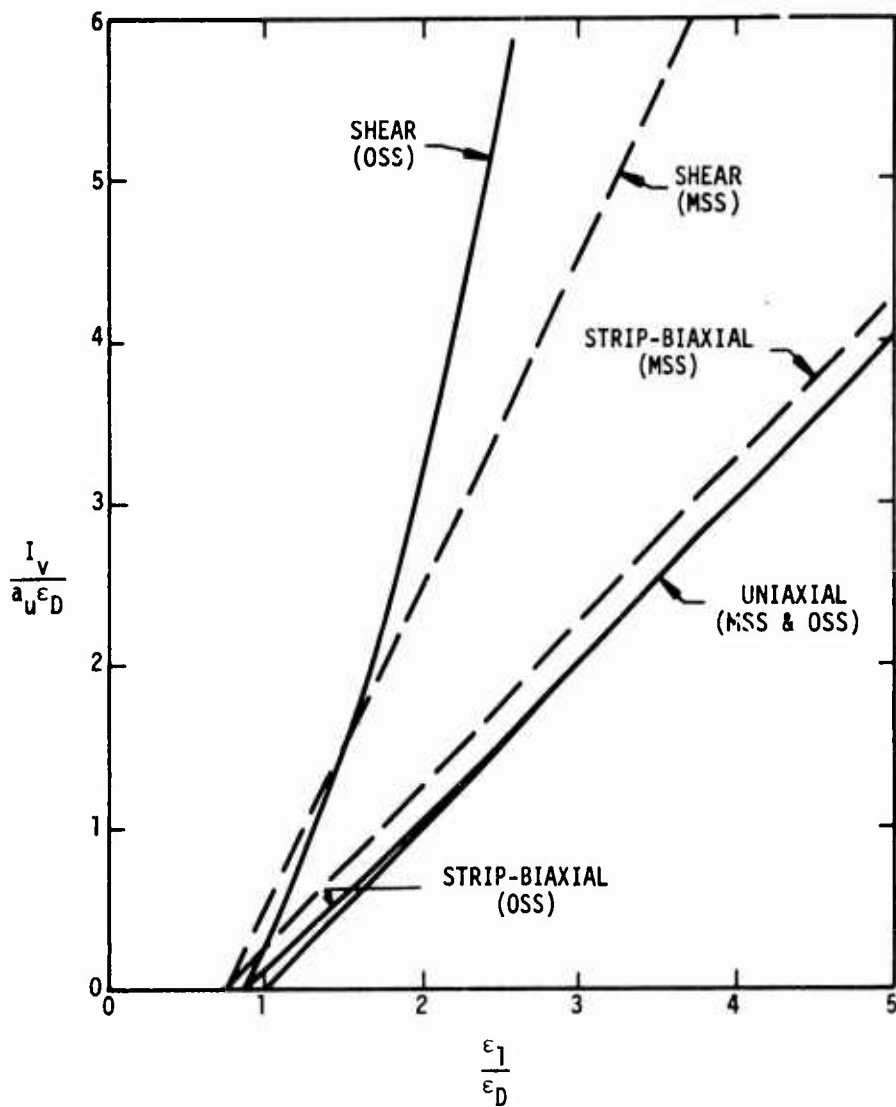


Figure 3. Comparison of Octahedral and Maximum Shear Strain Theories for  $a_u = 1$ .

is the slope of the dilatation vs. strain line in uniaxial tension; also,  $\epsilon_D$  is the value of uniaxial strain at which the dilatation line intersects the strain axis. The same values of  $a_u$  and  $\epsilon_D$  were used in both theories so that the same vacuole dilatation would be predicted for the uniaxial test. With the normalized variables used in Figs. 1-3, the graphs are independent of  $\epsilon_D$  and the predictions in Fig. 1 are independent of  $a_u$  as well; the range  $0 < a_u \leq 1$  in these figures brackets the range of values  $a_u$  observed for solid propellant under constant strain rate.

It is seen that, for given  $a_u$  and  $\epsilon_D$ , the following inequality is true for each theory:

$$I_v \text{ (uniaxial)} < I_v \text{ (biaxial)} \leq I_v \text{ (shear)} \quad (90)$$

Moreover, except for the shear prediction in Fig. 3, the MSS theory predicts a greater dilatation than the OSS theory in each test. These observations provide a basis for evaluating the relative accuracy of each theory from experimental data. Note that, according to these figures, use of shear and uniaxial data is better for this purpose than biaxial and uniaxial data when  $a_u$  is close to unity.

#### E. Microstructural Damage Theory

In this section the damage parameters and their effect on constitutive equations are examined in the context of viscoelastic fracture mechanics theory. First, however, we shall consider their role in the special dilatational constitutive equations (64) and (65), and in the shear equation (19b) with respect to vacuole dilatation.

Vacuole dilatation: According to Farris' microstructural model for vacuole dilatation [11], the volume fraction of solids about which vacuoles exist is proportional to the slope of the vacuole dilatation vs. uniaxial strain curve; experimental studies showed that this constant of proportionality is approximately unity [11]. Thus, the increase of dilatation with strain when  $dI_v/d\epsilon_u = \text{constant}$  is attributed to expansion of the cavities around the particles. With this model as motivation, let us now suppose for the sake of argument that (i) the relative change in damage parameters  $\beta_K$  is small when  $dI_v/d\epsilon_u$  is constant and (ii) this change per cycle remains small in subsequent unloading and loading cycles. We are assuming, in effect, that the major change in  $\beta_K$  occurs during the first loading as the invariant  $\tilde{I}_2$  (or  $\epsilon_g$ ) is increased from zero to its value when  $dI_v/d\epsilon_u$  first becomes constant, and that there is little, if any, rehealing when the specimen is unloaded.

In Farris' model [11] and in the model proposed above it is not actually necessary to assume the microstructural damage is entirely in the form of dewetting. The case in which many (or all) particles have a skin of binder adhering to them is not precluded and, as a result, the term vacuole dilatation, rather than dewetting, is used in this report.

Referring now to the simple constitutive relations Eq. (19) we see that if the above two suppositions are valid then the parameters  $K_e$  and  $G_e$  are the bulk modulus and shear modulus, respectively, in the range  $\tilde{I}_2 < b^2$ , after the sample has undergone strains for which  $\tilde{I}_2 > b^2$ . Some change in these parameters from cycle-to-cycle can be expected as additional damage occurs with each cycle. The bulk modulus  $K_e$  will be less than that for the undamaged propellant since the specimen, after being unloaded,

will have a larger void volume fraction than existing in the undamaged propellant; this point is supported by the experimental data in Section III.

The above model can be easily incorporated into viscoelastic constitutive equations. For example, referring to Eq. (44), in which all three material property functions depend on the elastic free energy  $F_e$ , we would simply use for  $F_e$  the special form in Eq. (14) together with Eqs. (17) and (18).

Microcrack initiation and growth: The state of the propellant at strains for which  $dI_v/d\epsilon_u$  is constant is the end result of an extensive amount of micro-flaw growth which occurs within the binder and/or between binder and filler particles. In this subsection we model the initial flaws as cracks and examine the implications of viscoelastic fracture mechanics theory in predicting the dependence of damage parameters on applied loading history. Thus, while the preceding subsection dealt with the final stage of damage, this subsection is concerned with the initial stage. Through a combination of the two models a constitutive theory applicable to all strains is proposed.

In the following theoretical development we assume, for simplicity, that the viscoelastic body is subjected to external uniaxial tensile stress,  $\sigma = \sigma(t)$ , and that the cracks propagate in only the so-called opening mode. Proposed generalizations to an arbitrary state of applied stress and to other crack propagation modes are given at the end of this subsection.

We suppose that there exists an initial distribution of cracks within the binder and possibly between binder and filler; the size of each crack

is assumed to be defined by a single parameter,  $2a_0$ , representing the length or diameter of the crack. As the loading on the body is increased from zero a given crack will start to grow when the stress intensity factor\* at the tip,  $N_c$ , exceeds a certain critical value,  $N_{or}$ . This value is identical to that for an elastic continuum whose Young's modulus,  $E$ , and Poisson's ratio,  $\nu$ , are equal to the long-time (rubbery) values  $E_r$  and  $\nu_r$  respectively, for the actual viscoelastic material [3]; thus

$$N_{or} = \sqrt{\frac{\Gamma E_r}{\pi(1 - \nu_r^2)}} \quad (91a)$$

where  $\Gamma$  is the fracture energy. If the stress intensity factor equals or exceeds the value based on initial (glassy) modulus  $E_g$  and Poisson's ratio

$$N_{og} = \sqrt{\frac{\Gamma E_g}{\pi(1 - \nu_g^2)}} \quad (91b)$$

then the crack velocity is predicted to be very high, and is limited only by wave action. We shall say the material surrounding a given crack is "tailed" if  $N_o \geq N_{og}$ ; the time at which  $N_{og}$  is first reached will be called the failure time.

The fracture theory in [3] can be used to predict time-dependent

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\*The stress intensity factor is defined in the singular stress distribution near the crack tip,

$$\sigma_y = N_o / \sqrt{x}$$

where  $\sigma_y$  is the stress normal to the crack plane and  $x$  is the distance ahead of the tip.

crack size when  $N_{or} < N_o < N_{og}$  and failure time for each crack in a propellant specimen under the following assumptions: (i) the rubber binder is linearly viscoelastic; (ii) the Poisson's ratio of the binder is constant (we shall assume  $\nu = 1/2$ ); (iii) all filler particles are rigid relative to the binder; and (iv) the propellant specimen is linearly viscoelastic with crack sizes fixed, and is under a spacewise uniform temperature.

Now the crack velocity,  $\dot{a}$ , when  $N_{or} < N_o < N_{og}$  is governed by the equation [3]

$$D(t_\alpha) = \frac{4\Gamma}{3\pi N_o^2} \quad (92a)$$

with

$$t_\alpha = \alpha/3\dot{a} \quad (92b)$$

and

$$\alpha = \pi^2 N_o^2 / \sigma_m^2 I_1^2 \quad (92c)$$

where existing information on rubber indicates that the fracture energy  $\Gamma$  and the stress distribution in the failure zone behind the tip,  $\sigma_m I_1$ , are constant. The quantity  $D(t_\alpha)$  is the creep compliance in uniaxial tension expressed in terms of the "effective time,"  $t_\alpha$ ; also,  $\alpha$  is the length of the failure zone behind the tip.

It is further assumed that during most of the time required for local failure, the creep compliance is given by the power law,\*

$$D(t) = D_1 (t/a_T)^n \quad (93)$$

where  $D_1$  and  $n$  are constants. Also, from the time the body is first loaded,  $t = 0$ , to the failure time for a given crack we assume the crack is isolated.

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\*However, at very short and long times,  $D(t) \rightarrow E_g^{-1}$  and  $D(t) \rightarrow E_r^{-1}$ , respectively.

That is, the crack is assumed to be so small that the only geometric parameter affecting crack growth is its own instantaneous size,  $2a$ ; in support of this point for cracks which are initially isolated, it is shown in [3] that the crack size at 90 percent of the failure time is only  $10^n \times (2a_0)$ ; e.g., if  $n = 0.3$ , most of the time required for failure is consumed while the crack doubles in size. The stress intensity factor for the  $i^{\text{th}}$  isolated crack satisfying the assumptions (i) - (iv) listed just above Eq. (92) can be written in the form [3]

$$N_{oi} = \sqrt{a_i} f_i \sigma \quad (94)$$

where  $2a_i$  is the size of the  $i^{\text{th}}$  crack and the coefficient  $f_i$  is a measure of state of stress existing in the binder in the neighborhood of the  $i^{\text{th}}$  crack relative to the applied stress;  $f_i$ , which will be called a stress concentration factor, is independent of material properties and depends only on the local particle geometry and spacing. According to the theory in [3], Eq. (94) is identical to the stress intensity factor in an elastic binder; thus, in principle, elastic analysis can be used to derive  $f_i$  if desired.

We combine Eqs. (92-4) and find the instantaneous size of the  $i^{\text{th}}$  crack at time  $t$ :

$$\frac{1}{a_{oi}^{1/n}} - \frac{1}{a_i^{1/n}} = f_i^q \int_0^t \left\{ \frac{3^{(1-n)} D_1 \pi^{(2n+1)}}{4n^n \Gamma \sigma_m^{2n} I_1^{2n}} \right\}^{1/n} \frac{\sigma}{a_T} dt \quad (95a)$$

where the curly bracket in the integrand will be a function of time if chemical aging occurs and/or if there is rehealing (which are accounted for through time-dependent properties). Also,

$$q \equiv 2(1 + \frac{1}{n}) \quad (95b)$$

The failure time of this crack is denoted by  $t_1$ , and is obtained by letting  $a_1 \rightarrow \infty$ ; it can be written in the form of a linear cumulative damage relation:

$$1 = \int_0^{t_1} \frac{dt}{t_{ci}} \quad (96a)$$

where  $t_{ci}$  would be the failure time for the  $i^{\text{th}}$  crack if the specimen had been subjected to a timewise constant stress,  $\sigma$ , (applied at  $t = 0$ ) equal to the actual stress at the time  $t$ , and had constant material and fracture properties equal to those actually existing at the time  $t$ :

$$t_{ci} = (A^{-\frac{1}{n}})(f_i^{-q})(a_{oi}^{-\frac{1}{n}})(M^{-\frac{1}{n}})(\sigma^{-q})a_T \quad (96b)$$

where  $A$  is a constant and is the group of terms in curly brackets in Eq. (95a) at a preselected reference state, and  $M$  is the ratio of this group at time  $t$  to the reference value. Without aging and rehealing  $M$  is unity; otherwise  $M = M(t)$ , and, although not essential, we assume  $M$  is the same function for all cracks.

We substitute Eq. (96b) into (96a) and solve for the stress concentration factor required to produce failure at time  $t_1$ :

$$f_i = \frac{Ba_{oi}^{-\frac{1}{nq}}}{||\sigma||_{Mq}} \quad (97a)$$

where

$$B \equiv A^{-\frac{1}{nq}} \quad (97b)$$

and  $||\sigma||_{Mq}$  is a "weighted" Lebesgue norm,

$$\begin{aligned}
||\sigma||_{Mq} &\equiv \left\{ \int_0^{t_1} \frac{1}{M^n} \sigma^q \frac{dt}{a_T} \right\}^{\frac{1}{q}} \\
&= \left\{ \int_0^{\xi_1} \frac{1}{M^n} \sigma^q d\xi \right\}^{\frac{1}{q}}
\end{aligned} \tag{97c}$$

in which  $\xi$  is reduced time,

$$\xi \equiv \int_0^t \frac{dt}{a_T} \tag{97d}$$

Of course, without aging and rehealing we set  $M = 1$  and obtain the Lebesgue norm itself in terms of reduced time. Note also that, from Eq. (95b),

$$\frac{1}{nq} = \frac{1}{2(n+1)} = \frac{1}{2} - \frac{1}{q} \tag{97e}$$

Thus, for all cracks in which  $f \geq f_1$  failure of the surrounding material has occurred. Cracks with smaller concentration factors have not yet failed. When the time  $t_1$  is exceeded for a given crack, the growth will be very rapid until the tips are arrested at filler particles and/or the tips move into a region of low stress concentration. We shall assume that the increase in the  $i^{\text{th}}$  crack size from the time  $t_1$  to the time the crack is arrested,  $t_{a1}$ , say (or, at least, until its velocity reduces to a relatively small value) is much larger than  $2a_0$ , and that the time difference  $t_{a1} - t_1$  is negligible compared to  $t_1$ . Let us denote the crack size at time  $t_{a1}$  as  $2a_{a1}$ ; since  $a_{a1} \gg a_{o1}$  and in view of the comments immediately following Eq. (93) we conclude that the influence of the  $i^{\text{th}}$  crack on overall mechanical response is felt approximately at the time  $t_1$ , and the magnitude of this influence is directly related to the total growth,  $2a_{a1} - 2a_{o1} \approx 2a_{a1}$ . Interaction between cracks when  $t > t_1$  is allowed.

Let us now predict the increment in specimen strain that results when the  $i^{\text{th}}$  crack grows to length  $2a_{ai}$  at the time  $t_i$ . In view of the linearity assumption this increment can be calculated by superposition. Specifically, consider the normal stress distribution that acts across an imaginary surface, where this surface is identical to the fracture surface which is later formed when the crack grows to length  $2a_{ai}$ . The increment in specimen strain due to actual crack growth is identical to that resulting from a sudden superposition of a pressure distribution at time  $t_i$ , whose magnitude is equal to the normal stress distribution existing across the imaginary surface following failure. This pressure is proportional to applied stress  $\sigma$ . Linearity plus dimensional analysis yield the following strain increment for a thermorheologically simple material if the applied stress is constant for  $t > t_i$ :

$$\epsilon_i = S_i \sigma D(\xi - \xi_i) \quad (98a)$$

where  $\xi$  is defined in Eq. (97d) and

$$\xi_i \equiv \int_0^{t_i} \frac{dt}{a_T} \quad (98b)$$

Also,  $D(\xi)$  is the uniaxial creep compliance of the propellant in terms of reduced time; it should be added that with rigid particles and linearity, dimensional analysis can be used to show that this creep compliance is proportional to the insitu compliance of the binder. The coefficient  $S_i$  is a constant.

Extension of Eq. (98) to a time varying stress following time  $t_{ai}$  is readily accomplished by superposition as long as further change in crack length is small compared to  $2a_{ai}$ . Specifically, introduce the

Heaviside unit-step function,

$$H(\xi - \xi_1) \equiv \begin{cases} 1, & \xi > \xi_1 \\ 0, & \xi < \xi_1 \end{cases} \quad (99)$$

where  $\xi_1 \equiv \xi(t_1)$ . Then the strain is

$$\epsilon_1 = S_1 \int_0^{\xi} D(\xi - \xi') \frac{d[H(\xi' - \xi_1)\sigma]}{d\xi'} d\xi' \quad (100)$$

Since the Dirac delta function,  $\delta$ , is given by

$$\delta(\xi - \xi_1) = \frac{dH(\xi - \xi_1)}{d\xi} \quad (101)$$

Eq. (100) can be written explicitly as

$$\epsilon_1 = S_1 \sigma_1 D(\xi - \xi_1) + S_1 \int_{\xi_1}^{\xi} D(\xi - \xi') \frac{d\sigma}{d\xi'} d\xi' \quad (102)$$

where  $\sigma_1 \equiv \sigma(\xi_1)$ .

We now turn to a statistical description of the microcracking problem, and thereby derive a constitutive equation by summing over the strains given by Eq. (102). First, define  $g_1$  as

$$g_1 \equiv \frac{f_1(a_{01})^{\frac{1}{nq}}}{B} \quad (103)$$

The stress concentration factor  $f_1$  and initial flaw size are random variables which, in turn, imply  $g_1$  is a random variable. Likewise,  $S_1$  is a random variable. Dropping the subscript (1) we write the expression for the number of cracks,  $N_c$ , having  $g$ -values between  $g$  and  $g + dg$ , and  $S$ -values between  $S$  and  $S + dS$  in the form

$$N_c = n(S, g) dS dg \quad (104)$$

The distribution function  $n = n(S, g)$  can be calculated from a distribution function in terms of the three random variables  $a_0$ ,  $f$ , and  $S$ , which will be demonstrated later. Equation (104) will be used in the constitutive theory development.

It is to be noted that  $g$  and failure time are directly related through a deterministic relation, which is obtained by combining Eqs. (97a) and (103),

$$g(\xi_f) = \frac{1}{||\sigma||_{Mq}} \equiv \left\{ \int_0^{\xi_f} M^n \sigma^q d\xi \right\}^{-\frac{1}{q}} \quad (105)$$

where  $\xi_f$  is now used as the generic variable representing reduced failure time.

The strain due to all microcracking,  $\epsilon_m$ , say, at reduced time  $\xi$ , is obtained by multiplying Eq. (100) by (104), replacing  $\xi_1$  by  $\xi_f$ , and integrating over all possible  $S$ -factors ( $-\infty < S < \infty$ ) and all possible  $g$ -values corresponding to  $0 \leq \xi_f \leq \xi$ . There results, finally,

$$\epsilon_m = \int_0^{\xi} D(\xi - \xi') \frac{d}{d\xi'} \left\{ \sigma \int_{g'}^{\infty} G(g) dg \right\} d\xi' \quad (106)$$

where

$$g' \equiv g(\xi') = \left\{ \int_0^{\xi'} M^n \sigma^q d\xi \right\}^{-\frac{1}{q}} \quad (107)$$

and  $G = G(g)$  is the following distribution function:

$$G \equiv \int_{-\infty}^{\infty} S n(S, g) dS \quad (108)$$

In view of the linearity assumption, the total axial strain,  $\epsilon$ , is

that due to the externally applied stress acting on undamaged propellant,

$$\epsilon_u \equiv \int_0^{\xi} D(\xi - \xi') \frac{d\sigma}{d\xi'} d\xi' \quad (109)$$

plus the strain  $\epsilon_m$ ; viz, from Eqs. (106) and (109),

$$\epsilon = \int_0^{\xi} D(\xi - \xi') \frac{d}{d\xi'} \left\{ \sigma \left[ 1 + \int_{g'}^{\infty} G(g) dg \right] \right\} d\xi' \quad (110)$$

where  $g'$  is given by Eq. (107) in terms of a weighted Lebesgue norm at time  $\xi'$ . In view of Eq. (107), we see  $\int_{g'}^{\infty}$  is a non-decreasing function of time (without rehealing).

A distribution function  $G(g)$  of particular interest is the power law

$$G = \begin{cases} G_1 g^{-r} & , \quad g \leq g_m \\ 0 & , \quad g > g_m \end{cases} \quad (111)$$

where  $g_m$ ,  $G_1$ , and  $r$  are constants; this function will be used later.

Before examining some special cases of Eq. (110) we shall derive the relation between  $n = n(S, g)$  in Eq. (104) and the distribution function for stress concentration factor and initial crack size. The distribution function  $m = m(S, a_0, f)$  is defined by the condition that  $N_{fa}$  is the number of cracks having  $S$ -values between  $S$  and  $S + dS$ ,  $a_0$ -values between  $a_0$  and  $a_0 + da_0$ , and  $f$ -values between  $f$  and  $f + df$ :

$$N_{fa} = m(S, a_0, f) dS da_0 df \quad (112)$$

The number of cracks  $N_c$  in Eq. (104) is equal to the integral of  $N_{fa}$  over the area in the  $a_0 - f$  plane bounded by the curves  $g = \text{constant}$  and  $g + dg = \text{constant}$ , where  $f$  and  $a_0$  satisfy Eq. (103). After equating  $N_c$

to the area there results

$$n(S, g) = B \int_0^{\infty} m(S, a_0, Bga_0^{-\frac{1}{nq}}) a_0^{-\frac{1}{nq}} da_0 \quad (113)$$

As an example, if  $m$  is a power law in  $f$ ,

$$m = m_1(S, a_0) f^{\alpha} \quad (114a)$$

where  $\alpha$  is a constant, we find that  $n(S, g)$  is given by a power law in  $g$ ,

$$n(S, g) = B^{1+\alpha} g^{\alpha} \int_0^{\infty} m_1(S, a_0) a_0^{-\frac{1}{nq}(1+\alpha)} da_0 \quad (114b)$$

By substituting this result into Eq. (108) the function  $G(g)$  is found to be the power law in Eq. (111) with  $r = -\alpha$  and  $g_m = \infty$ .

We now examine two special cases of Eq. (110) in order to help bring out the physical significance of this constitutive equation.

Elastic specimen: It is assumed that the creep compliance appearing in Eq. (110) is a constant,  $D$ , say; but the compliance in the fracture theory is still the power law, Eq. (93). These assumptions are not inconsistent. This point follows from the fact that the effective time  $t_{\alpha}$  in fracture Eq. (92) is typically several decades smaller than that governing the overall mechanical response of the binder [3]; thus, for example, crack growth may be controlled by viscoelastic processes at the same time the binder response is essentially in its long-time elastic response range.

Equation (110) reduces to

$$\epsilon = D\sigma \left\{ 1 + \int_g^{\infty} G(g) dg \right\} \quad (115)$$

where

$$g = g(\xi) = \left| \left| \sigma \right| \right|_{Mq}^{-1}$$

Equation (115) shows that the microscopic damage is characterized by a single function of the weighted Lebesgue norm  $||\sigma||_{Mq}$ , as in Eq. (110). This result is analogous to that obtained by Farris [2], but the role of stress and strain is reversed.

The power law distribution Eq. (111) reduces this theory to

$$\epsilon = D\sigma \left\{ 1 + \frac{G_1}{r-1} [ (||\sigma||_{Mq})^{r-1} - g_m^{1-r} ] \right\} \quad (116a)$$

when  $r \neq 1$ , and

$$\epsilon = D\sigma \left\{ 1 + G_1 \ln[||\sigma||_{Mq} g_m] \right\} \quad (116b)$$

when  $r = 1$ . Solution (116) is valid for only the range  $||\sigma||_{Mq} \geq g_m^{-1}$ ; when  $||\sigma||_{Mq} < g_m^{-1}$  failure has not occurred and one must set  $G_1 = 0$ . If  $g_m = \infty$ , the integral in Eq. (115) converges only if  $r > 1$ ; for this case Eq. (116a) shows that the strain will be approximately homogeneous to degree one in stress if  $r$  is close to unity.

Creep of a viscoelastic specimen: We set  $\sigma = \sigma_c H(\xi)$ , where  $\sigma_c = \text{constant}$ , and use the viscoelastic theory to predict creep compliance with microcracking,  $D_c \equiv \epsilon/\sigma_c$ . For simplicity, isothermal behavior ( $a_T = 1$ ) without rehealing and aging ( $M = 1$ ) is assumed and both power laws Eqs. (93) and (111) will be used with  $g_m = \infty$ .

From Eq. (107),

$$g' = g(t') = \sigma_c^{-1} (t')^{-\frac{1}{q}} \quad (117)$$

where we have set  $\xi' = t'$ . Equation (110) yields

$$D_c \equiv \frac{\epsilon}{\sigma_c} = D_1 t^n \left[ 1 + \frac{G_1 B}{q} (\sigma_c)^{r-1} t^{\frac{r-1}{q}} \right] \quad (118)$$

where the constant B is a Beta function,

$$B \equiv \int_0^1 (1-u)^n (u)^{\frac{1}{q}} (r-1)^{-1} du \quad (119)$$

For propellant  $n \approx 0.2$ , which implies  $q \approx 12$ , and therefore if  $r$  is close to unity we see  $D_c \sim t^n$  and that  $D_c$  is nearly independent of stress. The value  $r = 1$  is not admissible since  $B = \infty$  for this case.

Generalizations of the constitutive theory with microcracking: The above constitutive theory, Eq. (110), is a special case of the nonlinear theory, Eq. (47), based on thermodynamics. Indeed, we may recover the present theory from Eq. (47) by assuming:

$$Q = \theta \quad (120a)$$

$$\frac{\partial F_s}{\partial \theta} = B(\infty) \theta / 9a_G \quad (120b)$$

$$\frac{\partial F_s}{\partial \bar{J}_2} = J(\infty) / 4a_G \quad (120c)$$

$$a_\epsilon = a_T \quad (120d)$$

$$\frac{1}{a_G} = 1 + \int_{g'}^{\infty} G(g) dg \quad (120e)$$

where

$$g' = \left\{ \int_0^{\xi'} M^{\frac{1}{n}} |A_1 \theta + A_2 \sqrt{\bar{J}_2}|^q d\xi \right\}^{-\frac{1}{q}} \quad (120f)$$

and  $A_1$  (or  $A_2$ ) is an arbitrary constant. However,  $A_2$  (or  $A_1$ ) must satisfy the following relation in order that the three-dimensional theory reduce to uniaxial Eq. (110):

$$A_2 = \sqrt{\frac{3}{2}} (1 - A_1) \quad (120g)$$

Clearly, there is a single damage parameter in this representation which reflects the extent of microcracking; it is weighted Lebesgue norm  $||A_1\theta + A_2\sqrt{J_2}||_{Mq}$  in Eq. (120f). Moreover, if  $A_1$  and  $A_2$  are positive, pressure ( $\theta < 0$ ) is seen to correctly suppress the amount of crack growth.

It should also be recalled that  $M$  reflects the effect of aging and/or rehealing. This function is unity in the absence of these effects, but otherwise is given by

$$M = \frac{D_1}{D_{1r}} \frac{\Gamma_r}{\Gamma} \frac{(\sigma_m I_1)_r^{2n}}{(\sigma_m I_1)^{2n}} \quad (121)$$

where subscript  $r$  denotes constant quantities corresponding to a pre-selected reference state; also, recall that  $D_1$  is the coefficient in creep compliance Eq. (93) and that  $\Gamma$  and  $(\sigma_m I_1)$  are fracture properties.

The above theory was developed under the assumption that cracks propagate in the opening mode. However, the equations governing fracture in shearing modes are believed to be analogous to the opening mode case [3] and, therefore, we suggest that Eq. (120) may be valid regardless of the crack mode. However, further study is needed to confirm this point or else to determine if the more general theory, Eq. (47), is valid.

It is important to recognize that the three-dimensional theory based on Eq. (47) along with Eq. (120) is identical to linear theory except stresses are multiplied by a scalar factor,  $1/a_G$ . Hence, the inverse formulation in which the stress tensor is expressed as a functional of the strain tensor likewise will be identical to linear theory except  $\sigma_{ij}$  is replaced by  $\sigma_{ij}/a_G$ . This latter formulation suffers from the fact that the Lebesgue norm is expressed in terms of stress invariants rather than strain invariants; consequently, it generally will not be possible to

obtain an explicit representation for stresses in terms of strains and strain invariants.

Let us now consider how the microcracking model can be combined with nonlinear constitutive equations to obtain a theory which is potentially applicable to a wide range of propellant behavior. First, it should be recalled that Eq. (110) is based on the assumption that cracks are (approximately) arrested after rapid growth. As the applied stress is increased one can expect these previously arrested cracks to again propagate, thereby producing significant vacuole dilatation and eventually gross failure. (It should be added that significant dilatation does not necessarily result from the first growth stage when the binder is relatively soft; e.g., when a crack is cut into a sheet of rubber having high ultimate elongation, and the sheet is stretched in a direction normal to the original crack plane, the crack may open so much that it again becomes a sharp crack with its plane parallel to the loading direction [1]. The net change in dilatation for this process is essentially zero.) If it can be assumed that the subsequent propagation obeys the previously developed model, we suggest that all damage may be characterized by the same function  $a_G$ , Eq. (120e), except the distribution function  $G(g)$  will depend on strain or stress invariants. Moreover, in the high stress range it probably will be necessary to account for nonlinear stress invariant-dependence in  $Q$  and in the derivatives of  $F_g$  appearing in Eq. (47). Similarly, strain formulation Eq. (30) may apply in the high strain range after the stress tensor is replaced by  $\sigma_{ij}/a_G$ .

## F. Thermodynamic Constitutive Equations with Implicit Pressure Dependence

The strain formulation, Eqs. (5) and (30), and special cases, e.g. Eqs. (19) and (44), are based on the assumption that, except for damage parameters, the nonlinearities are defined by strain (rather than stress) invariants. In principle, one can retain the relatively simple forms of the special cases, but yet account for large superposed pressures. Referring to the thermodynamic theory in [17], it is easily shown that the Eqs. (5) and (30), and resulting special cases, may be applied to deformations superposed on the pressurized state. Namely, one interprets the stresses and strains,  $\sigma_{ij}$  and  $\epsilon_{ij}$ , as values which are added to the values existing in a reference pressure state. All material properties may then depend on this pressure as well as strain invariants. In grain analysis, one could select as reference pressure that in the bore, and then account for its time-dependence just as one does for a spacewise uniform, transient temperature.

## G. Generalization for Finite Strains

In all preceding three-dimensional equations make the substitutions [12],

$$\begin{aligned}\epsilon_{ij} &\rightarrow E_{ij} \\ \sigma_{ij} &\rightarrow \frac{\rho_0}{\rho} \tau^{ij}\end{aligned}\tag{122}$$

where the deviatoric components of  $E_{ij}$  and  $\tau^{ij}$  are calculated by using the same definitions as for small strain theory and

$E_{ij}$  = Lagrangian (covariant) strain tensor

$\tau^{ij}$  = (contravariant) stress tensor referred to convected coordinates and measured per unit area of the deformed body.

$\rho_0, \rho$  = density in the undeformed and deformed states, respectively.

### III. EXPERIMENTAL INVESTIGATIONS

#### A. Test Equipment and Procedures

Poker chip tests: These tests were made on ANB-3335-1 solid propellant samples furnished by Aerojet Solid Propulsion Company (ASPC). As received, the samples were 4.5 by 4.5 by 0.33 inches. The upper and lower surfaces had been machined to attain the 0.33 in. thickness. Therefore, before attempting to bond these samples to the plattens used for loading, all loose oxidizer particles on the surface of the samples had to be removed; two methods were tried. The first method was to spread Duco cement on the surface of the propellant sample and then press a gauze bandage down firmly onto the cement. After the Duco cement dried for eight hours at room temperature, the gauze along with the cement, and hopefully the loose oxidizer particles, were gently peeled back from the surface of the propellant sample. This procedure was based on previous experience by others, in which it was found to lead to very good bonds. Two initial samples cleaned by the above technique and bonded to the steel plattens turned out to fail under low loads, with gross tearing occurring near the bond line where the material was extremely soft (probably due to the Acetone in Duco cement).

The second method used to remove the loose oxidizer particles was to press down strips of three-inch wide surgical adhesive tape across the surface of the propellant and then peel back gently. All samples used in the mechanical property tests were prepared in this way.

Steel plattens 0.25 in. thick and 4.00 inches in diameter were sand

blasted by a medium grit in order to prepare them for bonding to the sample. The surfaces were then cleaned using Acetone.

Uralane 8615 epoxy compound, a two-part epoxy mixed in approximately equal parts by weight and obtained from Furane Plastics, Los Angeles, California, was used to bond the propellant samples to the plattens. This epoxy is a black material which has a pot life of approximately twenty minutes once the two components are mixed and a complete curing time of about twenty-four hours. The mixed epoxy was placed on both propellant surfaces and spread as thinly as possible to eliminate bubbles. Two steel plattens were fixed in a lathe using centered pull rods which had been screwed into each plate. A poker chip specimen was completed and made ready for curing by placing the propellant coated with epoxy between the two plattens and then mechanically forcing the plattens against the samples. Since the samples would slide out if left alone, several pieces of tape were used to hold the sample centered on the plattens. The bonded sample was allowed to cure for twenty-four hours in this position at room temperature.

The specimen was then turned in a lathe at a very slow speed and excess propellant was trimmed off even with the steel plattens. Completed poker chip specimens were stored in a dry refrigerator maintained at 74°F and containing a desiccant to maintain low humidity.

Just before a test, a teflon coated thermocouple girth wire was placed around the outside of the specimen midway between the two plattens, as shown in Fig. 4. One end of the girth wire was stripped and two closely spaced dots of solder were placed on this end of the wire; by



Figure 4. Poker-Chip Specimen Showing  
Girth Wire, LVDT's, and Micrometers.

inserting a horseshoe-shaped 1/4 in. long x 36 gage wire holder in between these closely spaced solder dots and into the propellant, the girth wire was secured at one end. This wire extended from the tiedown point completely around the circumference of the specimen and came off tangent to the tiedown point to then connect to a lever arm. Horseshoe-shaped portions of bare 36 gage wire were stuck into the propellant over the girth wire at intervals of approximately 0.4 inches, to hold it in position along the mid-plane between the two plattens.

An aluminum plate approximately 1/4 in. thick by 6.5 in. diameter was mounted on top of the upper platten and fastened securely with a nut on the pull rod. This upper plate was designed to accommodate three vertical micrometers at 120 degree spacings. Another aluminum plate of the same size and an S-shaped bracket were mounted securely on the lower side of the lower platten by tightening the nut on the lower pull rod. This lower aluminum plate was designed to accommodate three linear variable differential transformers (LVDT's) aligned with shafts from the three vertical micrometers on the upper plate. These vertical micrometers had a total travel of 0.05 in. which allowed us to make very fine in-place calibrations.

For tension tests the upper pull rod was attached to a universal joint which was in turn attached to a single lever arm loading frame, (see Fig. 5). The lower pull rod was attached to a universal joint which was in turn attached to a slip joint which engages only when the lever arm is loaded. An LVDT was attached to the S-shaped bracket that extends from beneath the lower platten to be in line with the girth wire. The other end

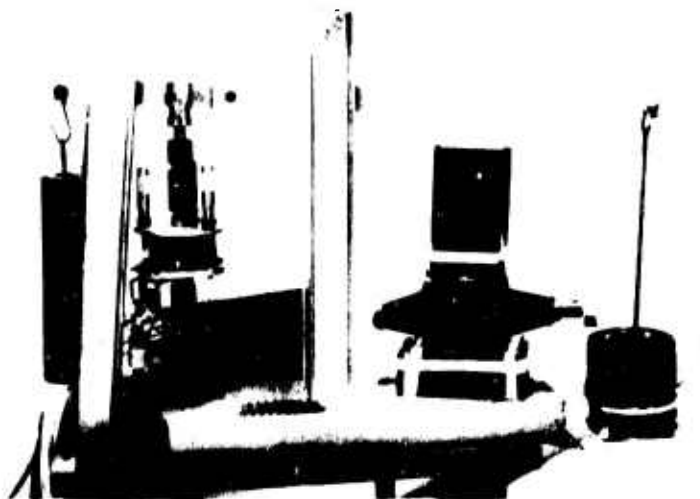


Figure 5. Poker-Chip Assembly used for  
Tensile tests.

of the LVDT was attached to a Chavetz micrometer which had a total travel of 1.0 in. A modified 4 - 4 1/2 in. hose clamp was attached to the lower platten to support a small L-shaped lever arm. The vertical arm of the lever was connected to the girth wire, while the horizontal arm was connected to a vertical wire extending to a slug within the LVDT mounted on the lower S-shaped bracket. The horizontal girth motion was thus transferred into a vertical motion and magnified by approximately four. With the Chavetz micrometer it was possible to attain an inplace calibration for the girth measurement. To insure that there was no sticking associated with the girth wire or LVDT's, a pulsing vibrator was attached to the frame of the test mechanism.

The three vertical LVDT's spaced 120 degrees apart around the sample were used to measure plate separation and to determine if there was bending in the sample. By averaging the three readings we obtained an overall average strain which, together with the girth measurement, enabled the determination of dilatation. Signals from all four LVDT's were fed into an amplification system that allowed us to obtain high gain settings and to maintain a linear output signal as a function of displacement for a given range.

For testing, the system was loaded to provide 10, 20, 35, and 50 psi average axial stress to the poker chip specimen. Testing was performed at a temperature of 74°F and at a relative humidity of between 34 and 40 percent. All tests were creep and recovery tests with cycles of five minutes creep, ten minutes recovery, and 15 minutes wait between cycles. There were one or two one-minute initial loadings at each load range before the

actual test to insure that the data readings would remain on scale and that the readings were still linear. Five to seven creep and recovery cycles were run for each load range, and only one load range was run per day. Compression tests were also run on poker chip specimens. The only difference in the compression test assembly was that instead of having the upper and lower universal joints attached to the upper and lower pull rods, respectively, heavy steel frames replaced the pull rods; one frame was used to attach the lower platten to the upper universal joint, and another frame connected the upper platten to the lower universal joint.

Strip-biaxial tests: Tests were performed on ANB-3066 and ANB-3335-1 solid propellant obtained from Aerojet Solid Propulsion Company. The biaxial dilatometer used for these tests was obtained from Hill Air Force Base on a loan basis and as received was in unworkable condition as originally manufactured by the CETEC Corporation. The unit was completely disassembled, and after extensive modification was put into working condition. The dilatometer, shown in Fig. 6, was designed to measure dilatation by two different methods. The first method relied upon direct LVDT measurements of decrease in cross-sectional thickness. The LVDT system consisted of spring loaded probes that slide on the surface of the specimen's sides. Unfortunately the probes were not only insensitive to the small thickness changes but also damaged the surface of the propellant at the point of contact. As a result the LVDT probes were removed entirely, and we relied upon the second method of dilatation measurement. This method was based on state-of-the-art gas dilatometric techniques such as those employed by Farris [11].

The biaxial dilatometer consists of two chambers, a specimen chamber and reference chamber, which are completely separate from each other. The

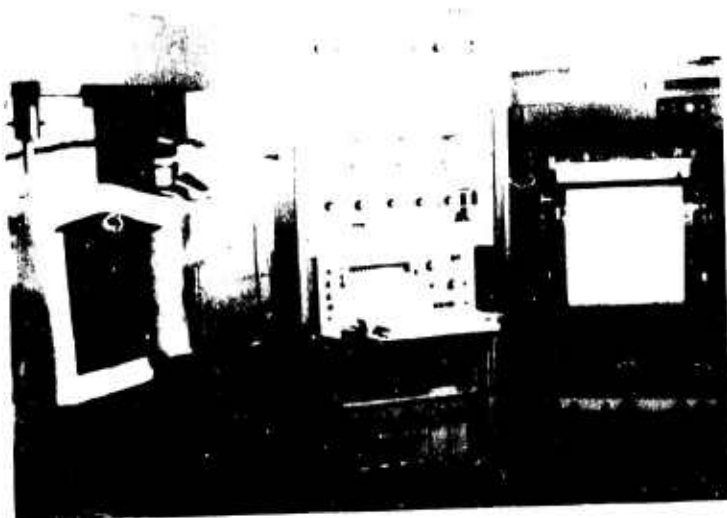


Figure 6. Biaxial Dilatometer Mounted in Instron Test Machine.

dilatometer was configured so that both chambers could be pressurized up to 1000 psi and equalized to the same pressure. Once all the leaks around the dilatometer, plumbing connections, door, shaft, and calibration micrometer were sealed at high pressure, the system was functional. The dilatometer was mounted in an Instron, and an extensometer was mounted to the shaft of the dilatometer to measure sample extension. Unlike other dilatometers which have a compensating shaft that extends from the reference chamber, the dilatometer used in these tests was not equipped with this reference chamber shaft; specimen chamber shaft movement was compensated electronically by coupling the shaft extension with the pressure change due to shaft movement alone.

Before each test, the unit was calibrated for volume change by inserting a precision micrometer shaft into the specimen chamber in increments to simulate a volume change of  $.00707 \text{ in}^3$  (for the samples used in our tests this corresponds to a volume change of about 0.5 percent). It was possible to resolve volume changes on the order of .01 to .02 percent over a relatively long period, provided the temperature remained constant. To insure constant test conditions, the tests were run in large walk-in chambers which were held to a constant temperature and humidity. The dilatometer and associated plumbing were wrapped thoroughly with insulation material (see Fig. 6) to prevent changes due to the body-heat of people in the room who are running the tests.

The propellant samples furnished by Aerojet were saw-cut into specimens with dimensions of 7.0 by 1.63 by 0.38 inches. Using a circular cutter, each end of each specimen was trimmed to remove the material included within a circular arc with an approximately one-inch radius connecting the two corners

at each end of the specimen, as shown in Fig. 7. The samples were then bonded to aluminum plates using the 8615 epoxy described in the poker-chip section above. The aluminum plates were prepared by first sand blasting the surface to be bonded and then placing masking tape around the plates so that the tape extended approximately 0.25 inches above the surface of the plates. The epoxy was then poured into the cups made by the masking tape to about half full. One 7.0 by 0.38 inch edge of the sample was pushed into the epoxy and against the aluminum plate. Care was taken to create a fillet around the sample as it emerged from the epoxy in order to provide for gripping and a gradual load transfer from the grips. A spacer was placed on each side of the samples to hold the propellant at the center of the aluminum plate while the epoxy cured for twenty-four hours. This process was then repeated for the opposite edge of the sample. After curing, the bonded samples were stored for at least twenty-four hours before testing in constant temperature and humidity walk-in chambers.

A bonded sample was fastened to loading rails and loaded into the dilatometer specimen chamber as shown in Fig. 8. The door was then put in place and bolted down.

If the test was to be run under pressure, the valve connecting the reference and specimen chambers was opened and the system was pressurized to the desired pressure. The valve was then closed to isolate the chambers again while the system stabilized for one to two hours. Just before running the actual test, the two chambers were equalized by opening the connecting valve and then closed to isolate them again. Also, as described above, the unit was calibrated for volume change. In addition, the internal load cell located within the dilatometer was calibrated.

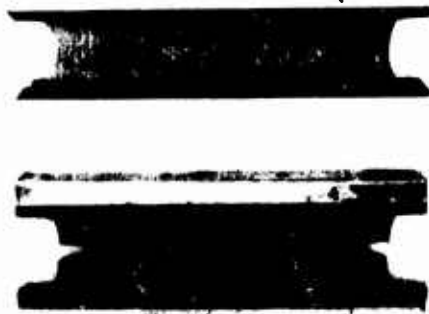


Figure 7. Unfailed and Failed Strip-biaxial Specimen End-Bonded to Aluminum.

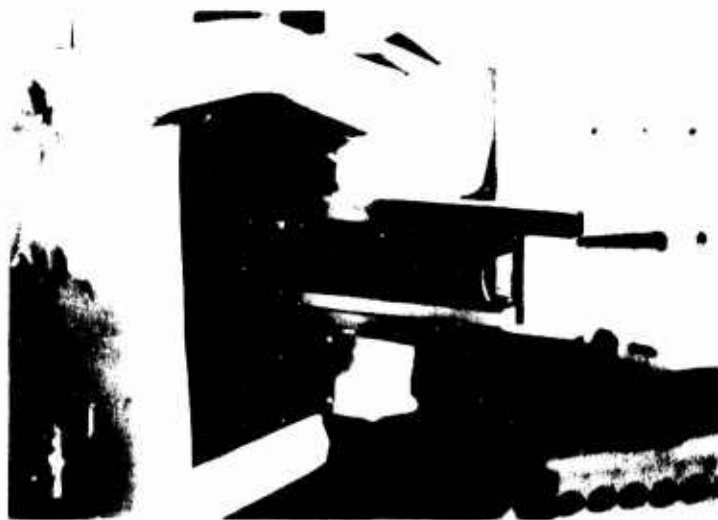


Figure 8. Strip-biaxial Specimen Partly  
Inserted in Dilatometer.

Several types of tests were run including constant strain rate to failure, ramp-relaxation, and cyclic loading and unloading before loading to failure. Sample displacement, volume change, and load were recorded on a light sensitive oscillograph recorder.

Uniaxial tests: These tests were run on AND-3066 and ANB-3335-1 Aerojet propellant using the same biaxial dilatometer used for the strip-biaxial tests. The uniaxial samples were made from the 7.0 by 1.63 by 0.38 inch strip-biaxial specimens. Instead of cutting circular arcs of material away from the ends as was done for the biaxial samples, the rectangular samples were cut completely through to within 0.2 inches of each edge at intervals of 0.37 inches along the length of the sample. The samples were then bonded to the aluminum plates as described for biaxial specimens. This procedure provides nineteen uniaxial samples to be tested at one time, which are shown in Fig. 9.

#### B. Experimental Data and Comparison with Analysis

Poker-chip tests: Figures 10-13 show compliances and dilatation obtained from tension tests performed on samples Nos. 1 and 2, while Figs. 14-17 show these quantities for compression of sample No. 2. The creep and recovery compliances are defined as follows:

$$D_{pc} \equiv \frac{\epsilon}{\sigma} \quad (123a)$$

$$D_{pc}^{(r)} \equiv \frac{\epsilon_r}{\sigma} \quad (123b)$$

where  $\sigma$  is the total axial load divided by platen area,  $\epsilon$  is the strain (based on platen separation) during the creep portion of one loading cycle,

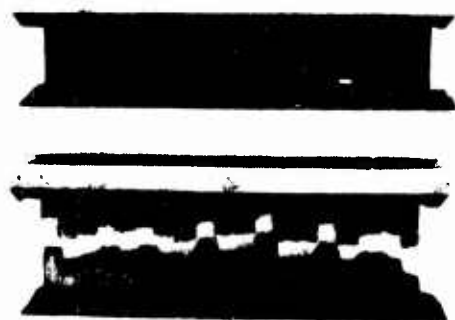


Figure 9. Unfailed and Failed Uniaxial Specimens  
End-bonded to Aluminum Plates.

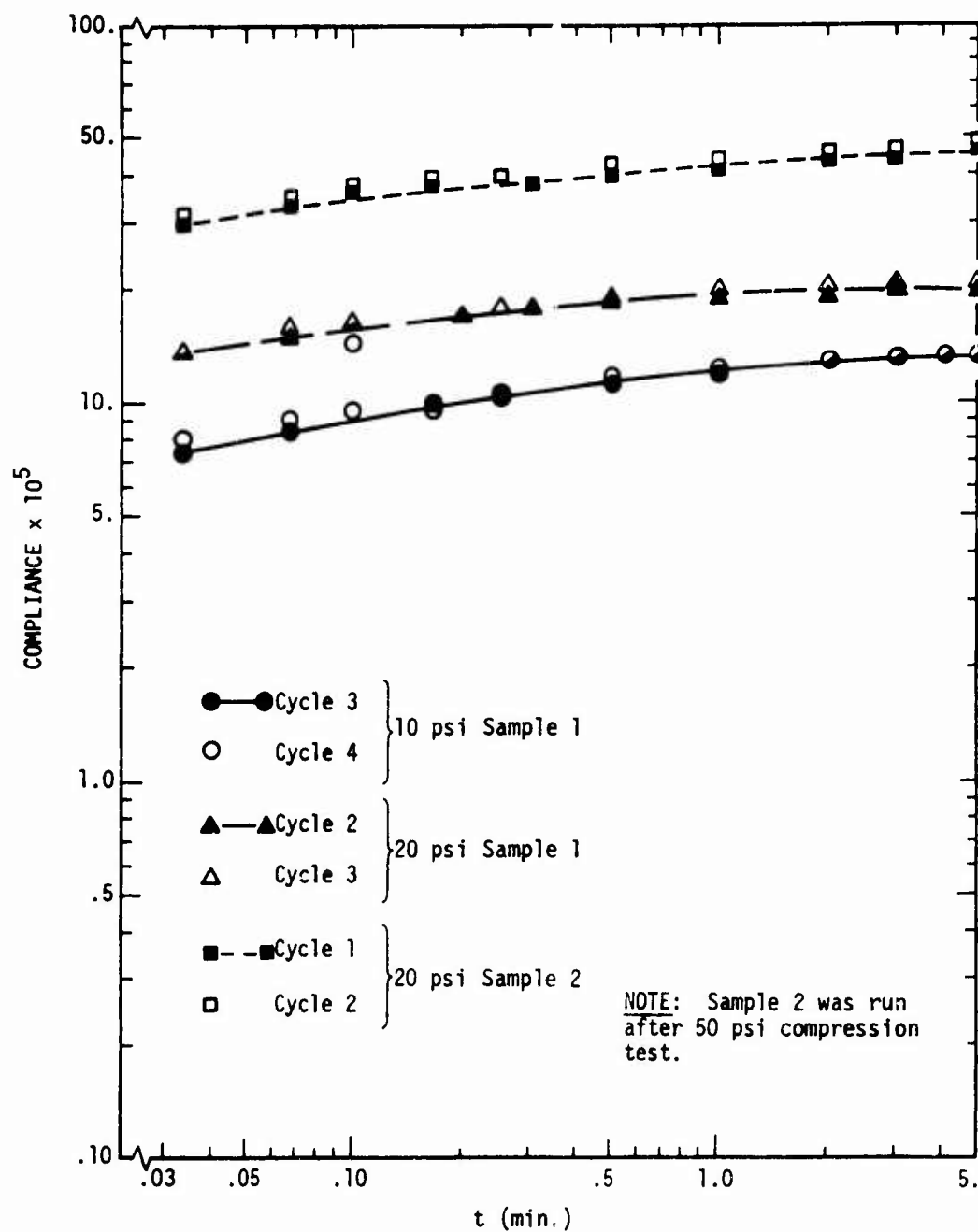


Figure 10. Poker Chip Creep Compliance in Tension.

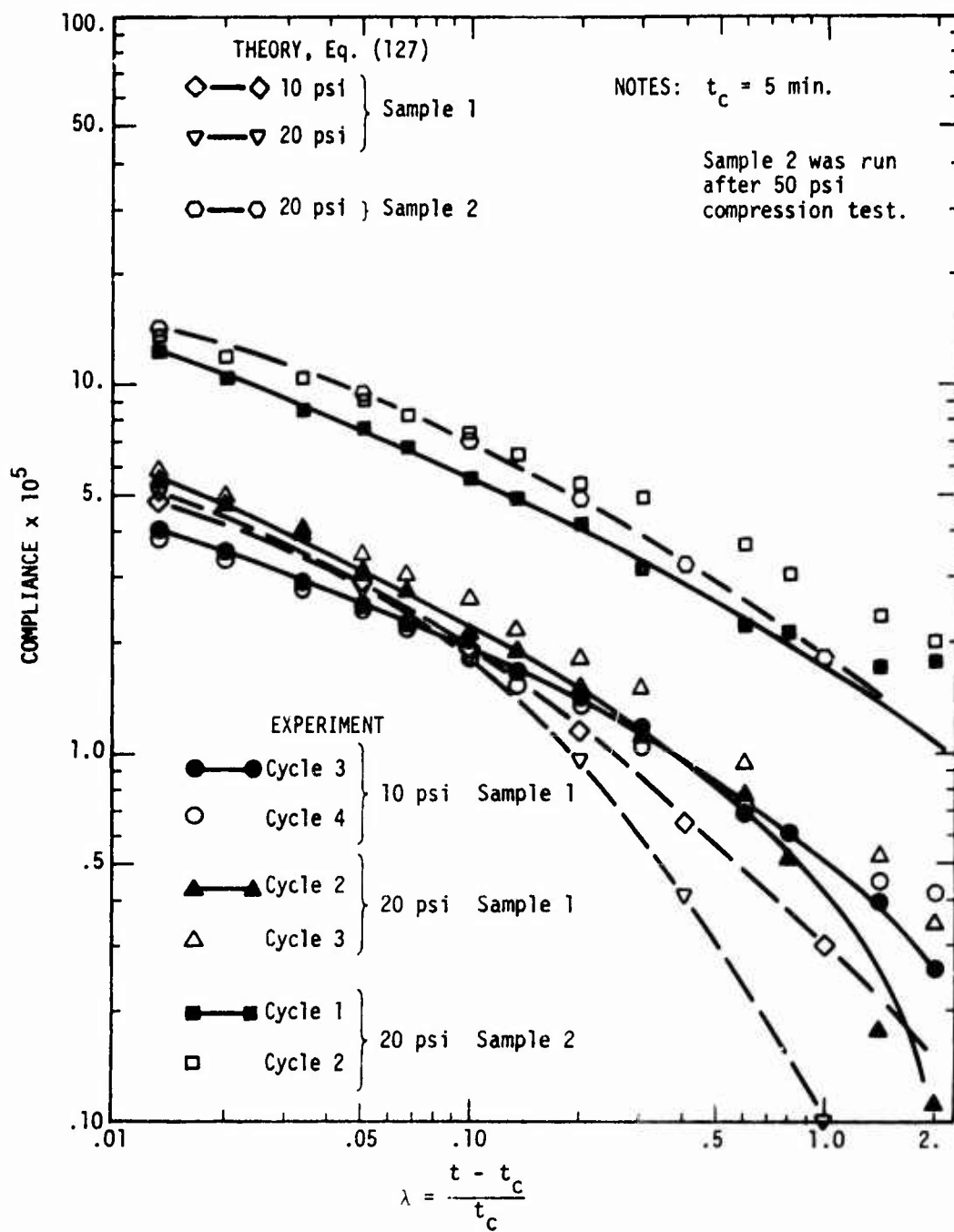


Figure 11. Poker Chip Recovery Compliance in Tension.

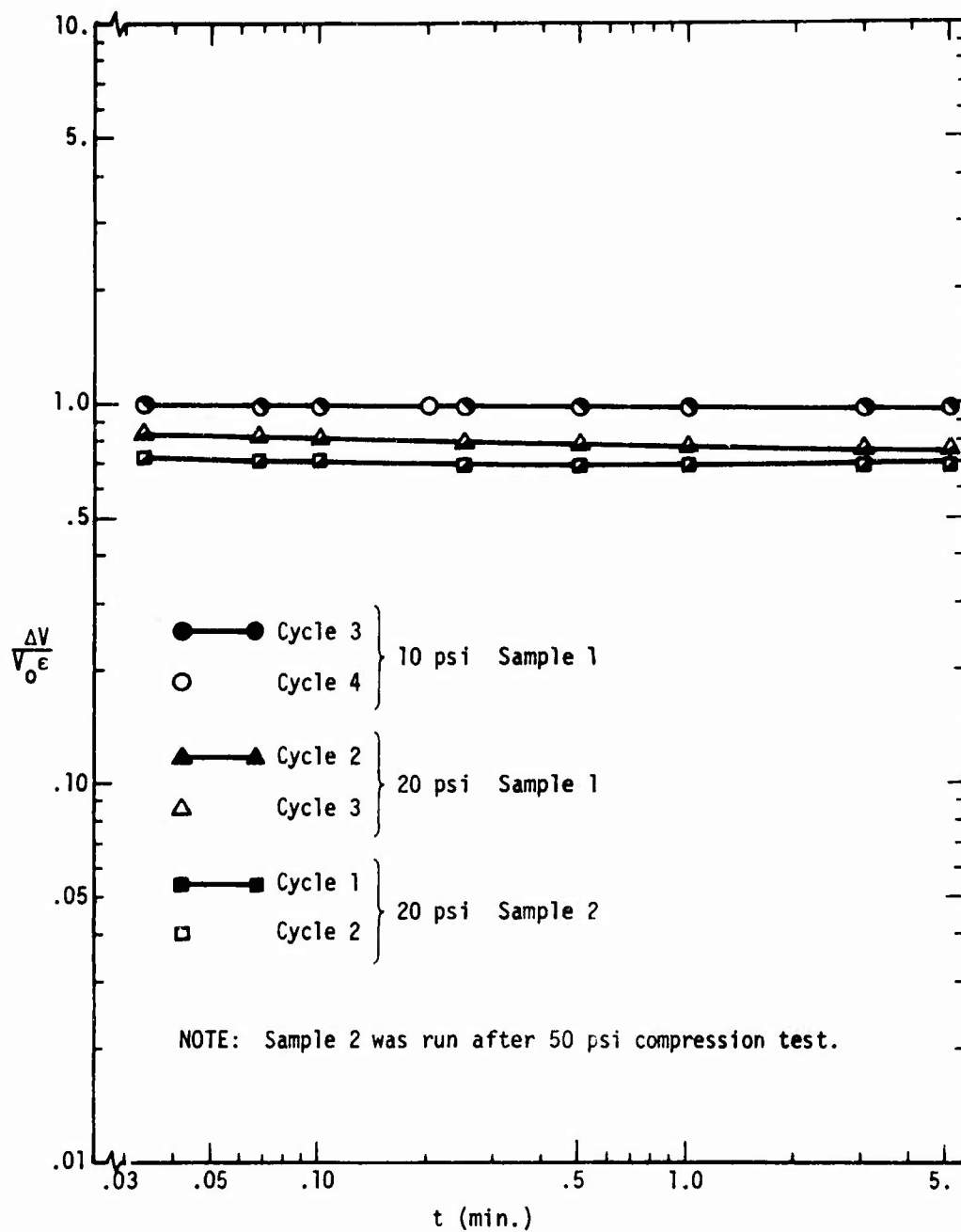


Figure 12. Poker Chip Dilatation in Tension-Creep.

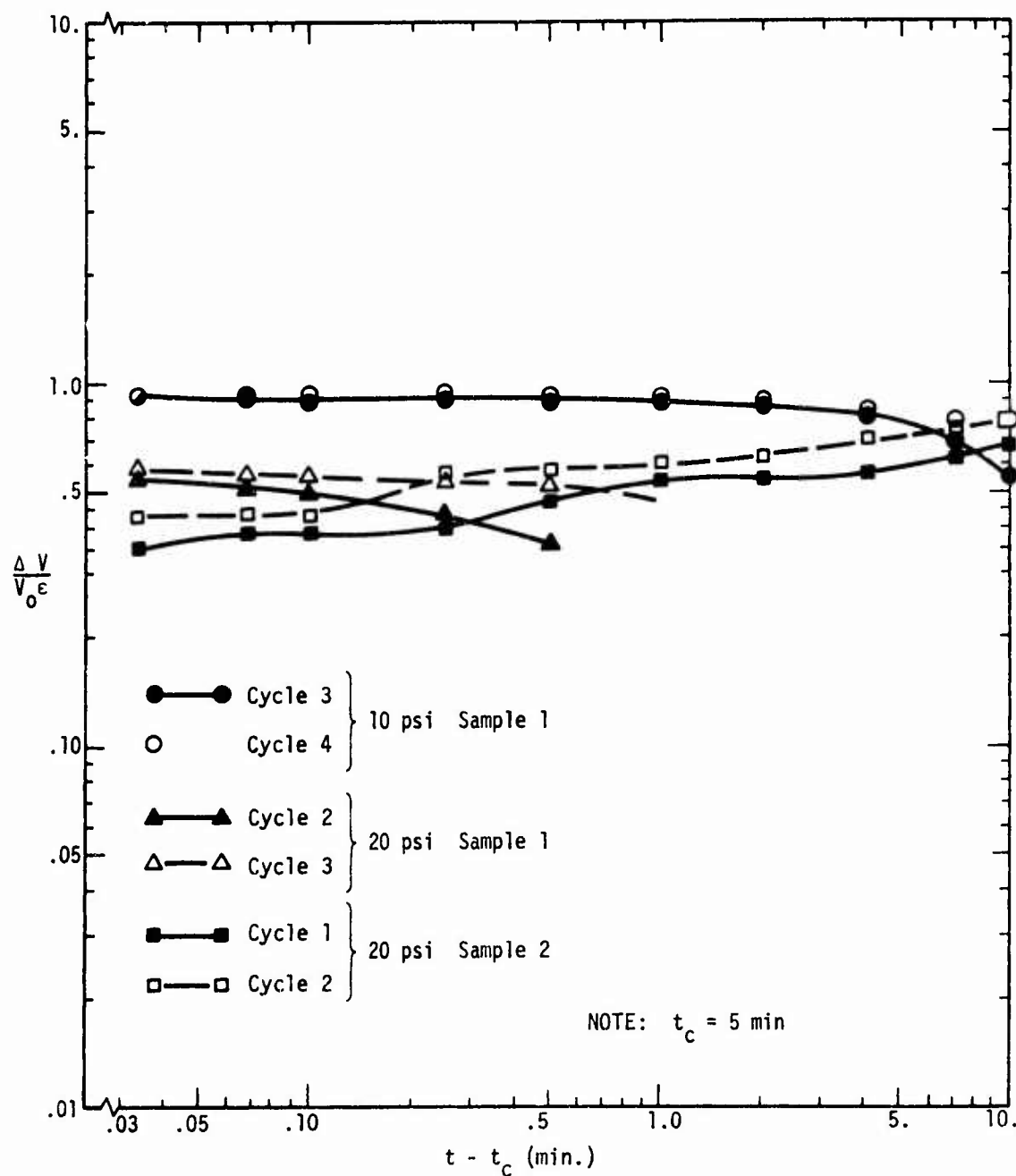


Figure 13. Poker Chip Dilatation in Tension-Recovery.

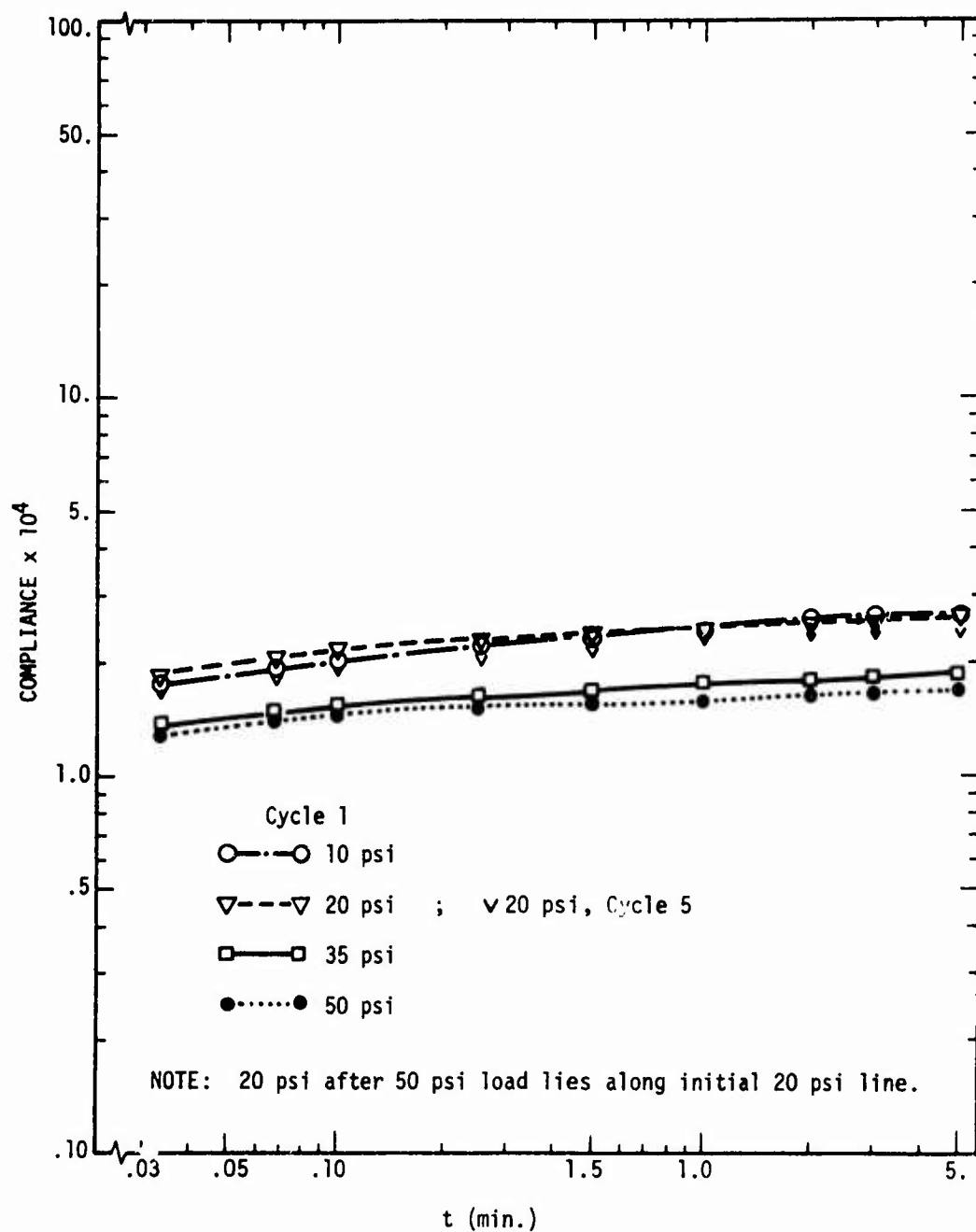


Figure 14. Poker Chip Creep Compliance in Compression.

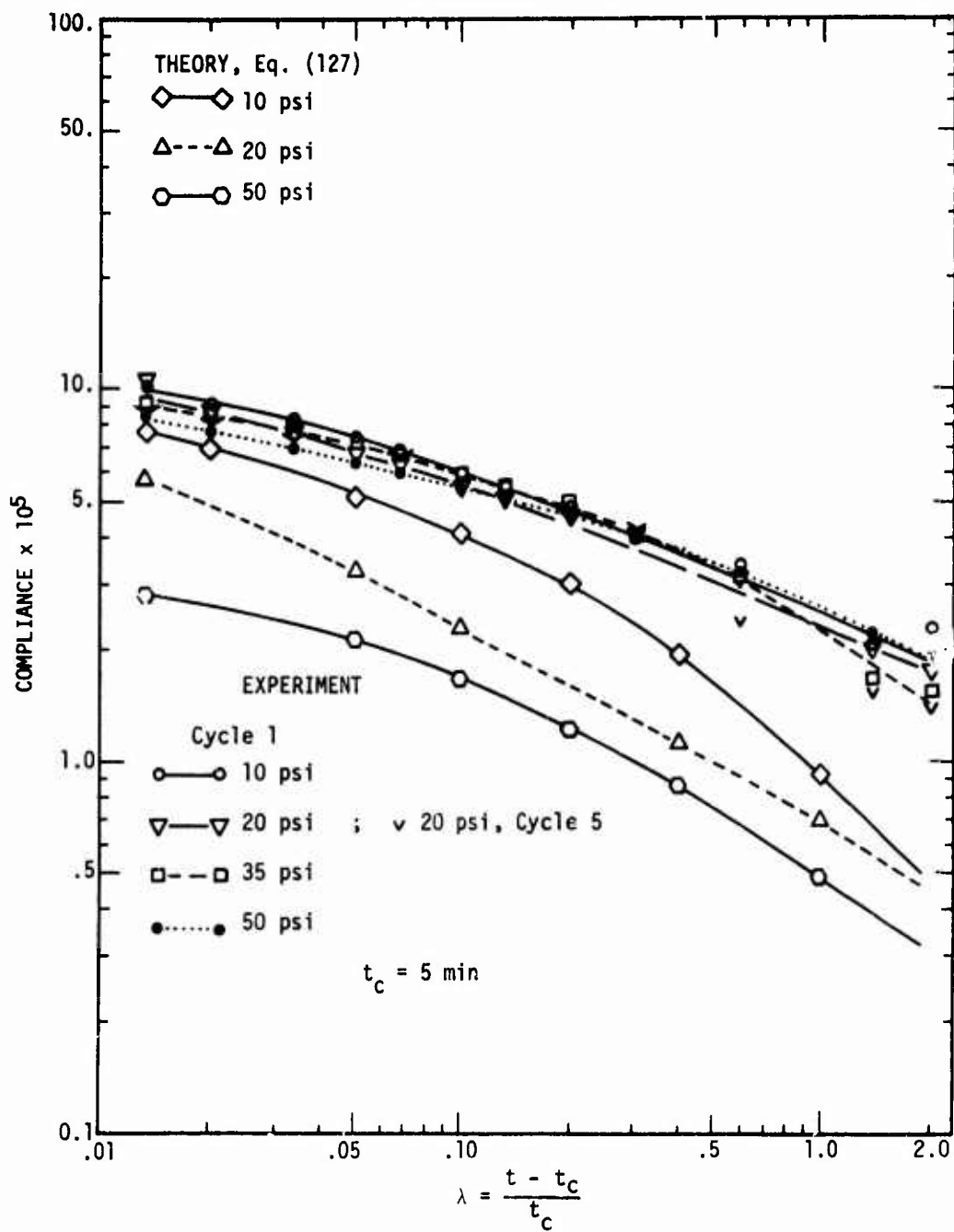


Figure 15. Poker Chip Recovery Compliance in Compression.

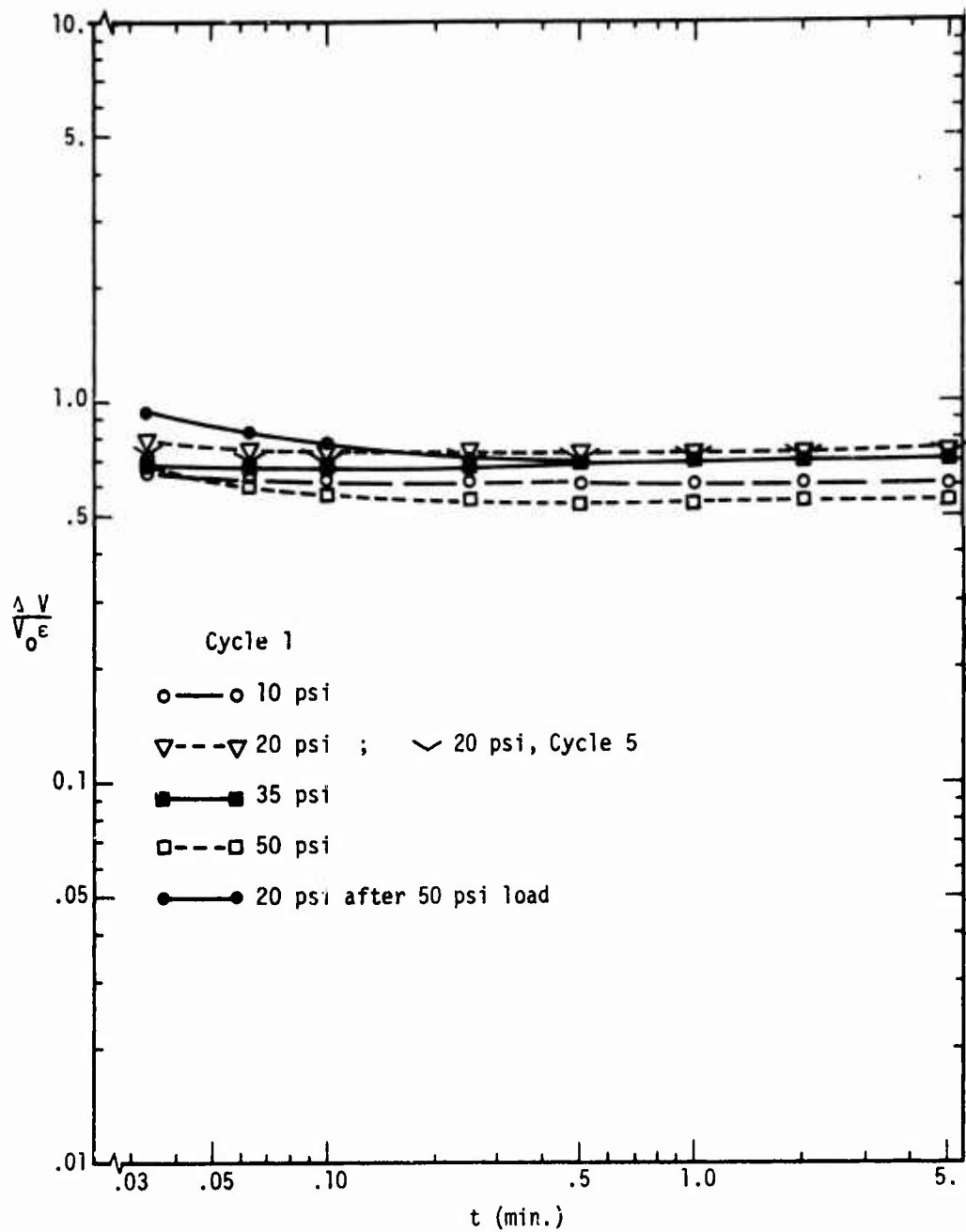


Figure 16. Poker Chip Dilatation in Creep-Compression.

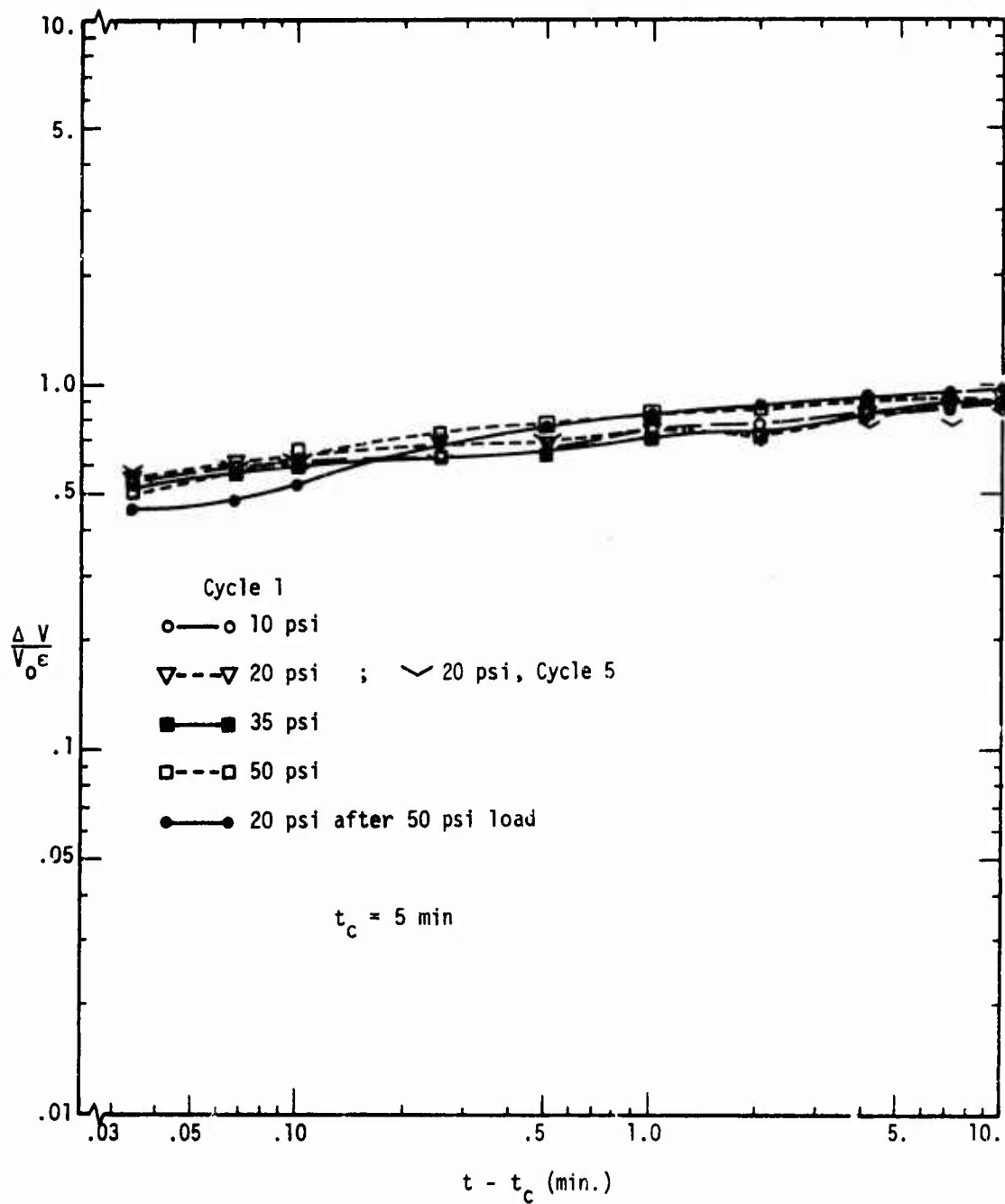


Figure 17. Poker Chip Dilatation in Recovery-Compression.

and  $\epsilon_r$  is the recovery strain (which is the strain following load removal). The cycle numbers shown on the graphs represent a loading and unloading sequence, with cycle No. 1 defining the first sequence after the specimen had been loaded once or twice for calibration purposes. Therefore some damage had already been incurred, even before the data labeled cycle No. 1 was obtained. Nonetheless, however, that in most cases for each stress level no further significant increase in damage (as measured by changes in compliance and dilatation) appears to have occurred as the sample was cycled.

The dilatation shown in these figures was found using the same procedure described in [ 4 ] for earlier work at TAMU; specifically, the following equation was used:

$$\frac{\Delta V}{V_o} = \frac{V_{pl} - V_{para}}{V_o} \quad (124)$$

where

$V_{pl}$   $\equiv$  volume displaced by moving platen

$V_{para}$   $\equiv$  volume swept out by revolving the parabolic area at the periphery around the loading axis.

As an aid in interpreting the compliance and dilatation data, we show in Fig. 18 a graph that enables various property ratios to be deduced from the experimental data. This graph was obtained from a linear quasi-elastic analysis of a compressible poker-chip using the equations in [ 4 ]; a condensed version of this graph also appeared in [ 4 ]. The following definitions apply:

$E_{pc} \equiv D_{pc}^{-1}$  = effective relaxation modulus of poker chip

$D_u$  = creep compliance under uniaxial loading

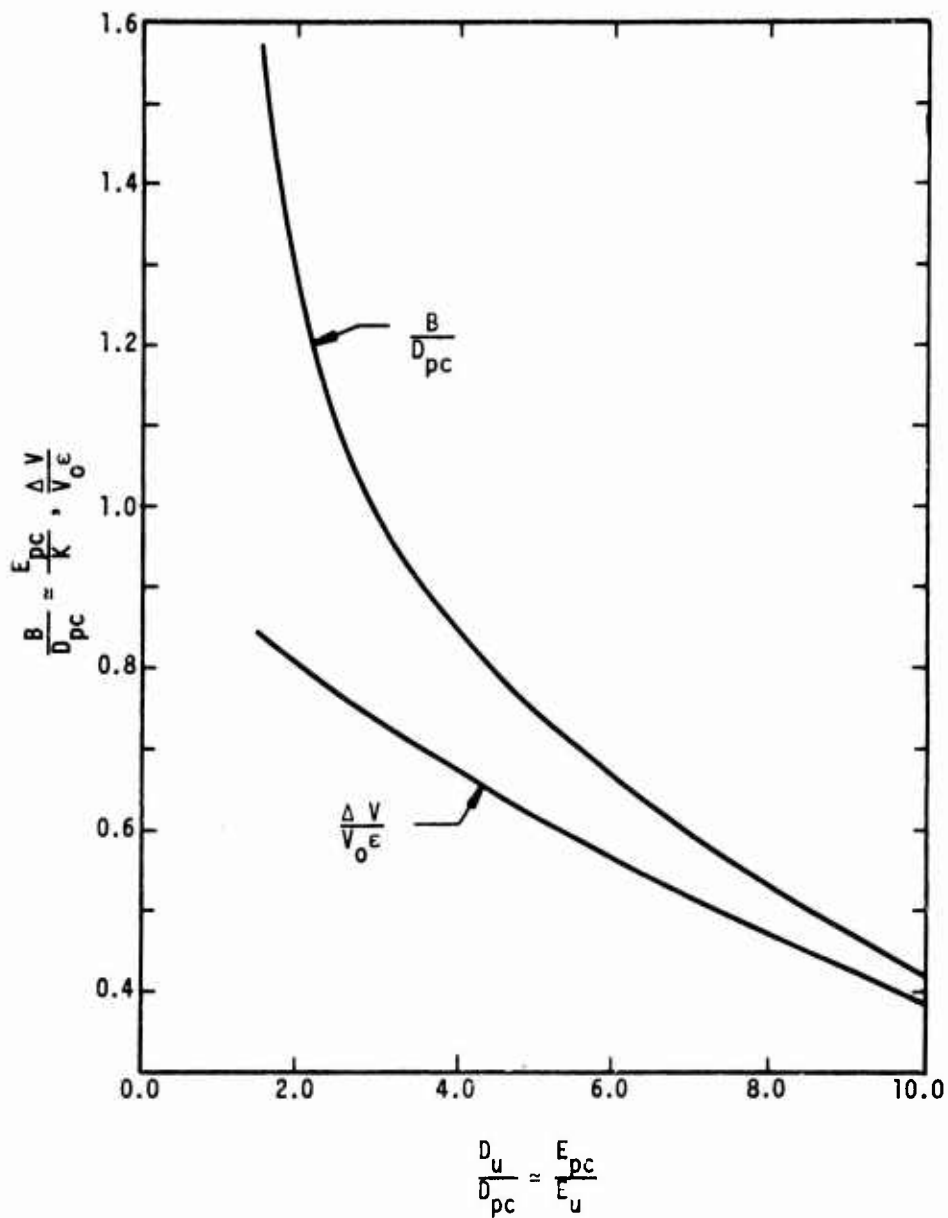


Figure 18. Property Ratios for Poker Chip (Dia/Thickness = 12).

$B$  = bulk creep compliance

$K$  = bulk relaxation modulus ( $\approx B^{-1}$ )

$E_u$  = relaxation modulus under uniaxial loading ( $\approx D_u^{-1}$ )

In order to illustrate the use of this graph let us consider some of the data in Figs. 10-17. The ratio  $\Delta V/V_0 \epsilon$  is reasonably constant in Fig. 12 and, for sample No. 2, has the approximate value of 0.7. Reading across and down from the  $\Delta V/V_0 \epsilon$  curve in Fig. 18 we find  $D_u/D_{pc} \approx E_{pc}/E_u = 3.5$ . Reading up to the  $B/D_{pc}$  curve and over to the ordinate we find  $B/D_{pc} \approx E_{pc}/K \approx 0.9$ .

From the compliance curve in Fig. 10 one can obtain  $D_{pc}$  at any time, and therefore calculate the remaining properties in these ratios. For example, at  $t = 0.1$  min,  $D_{pc}^{-1} \approx 3000$  psi, and therefore  $K \approx 3300$  psi. This extremely low value predicted for bulk modulus (which is typical of the values obtained from the other data) is probably in error because of non-linear effects. However, it is believed that its order of magnitude is not unreasonable since the specimen probably has a significant void fraction as a result of prior loadings.

An observation of interest is that if  $\Delta V/V_0 \epsilon$  is independent of time, as it is in Fig. 12 and in Fig. 16 except at short times, linear theory can be used to show that Poisson's ratio is constant. Now, a composite material consisting of a relatively incompressible viscoelastic binder together with voids and rigid particles can be shown to have a constant Poisson's ratio; this result is easily established by means of the linearity assumption plus dimensional analysis. This latter observation is, of course, consistent with the hypothesis that the poker chip specimens, as tested, contained a

large initial void fraction due to previously induced damage.

A partial check on the microcrack theory in Section II-E is provided by a comparison of creep and recovery data. First of all, consider the following isothermal constitutive equation relating average axial stress applied to the poker-chip,  $\sigma$ , and the axial strain,  $\epsilon$ :

$$\epsilon = \int_0^t D_p(t - t') \frac{dP(\sigma)}{dt'} dt' \quad (125)$$

where  $P = P(\sigma)$  is a nonlinear function of stress. Also  $D_p$  is the linear viscoelastic poker-chip creep compliance. The creep and recovery compliances are predicted to be, respectively,

$$D_{pc}(t) = \frac{P}{\sigma} D_p(t) \quad (126a)$$

$$D_{pc}(r) = \frac{P}{\sigma} [D_p(t) - D_p(t - t_c)] \quad (126b)$$

where  $t_c$  is the time at which the load is removed. Combining Eqs. (126a) and (126b) we find

$$D_{pc}(r) = D_{pc}(t) - D_{pc}(t - t_c) \quad (127)$$

Since Eq. (125) with  $P = \sigma$  is an exact equation for linear materials, we conclude that the recovery compliance for this special nonlinear theory is related to creep compliance in the same way as in linear theory. Equation (127) has been used to construct the theoretical recovery curves shown in Figs. 11 and 15. Considering the scatter in experimental data, predictions for the tension test are quite good. However, the theory is seen to underpredict recovery compliance in compression; the difference is believed to be due, at least in part, to rubbing between flaw faces which would impede recovery from a compressed state. In both tension and compression

the creep compliance varies appreciably with stress level.

Now, refer to the theory with microcracking. Rigorously, a nonlinear stress analysis of the poker-chip is required to interpret the data because the stresses are not spacewise uniform. However, we will argue that Eq. (110) is approximately valid for the tension tests after replacing  $D$  by  $D_p$ , if the underlying three-dimensional theory, Eqs. (47) and (120), are themselves correct.

Considering linear theory first, if Poisson's ratio,  $\nu$ , is constant and the material is linear, the stresses throughout the poker-chip can be shown to be timewise constant during creep and zero during recovery. In tension tests, the thickness-averaged normal stresses are approximately equal and distributed parabolically across the radius (with the maximum occurring at the center), while the thickness-averaged shear stress increases linearly with radius from the center [18]. With this observation in mind, and assuming the stresses in a nonlinear poker-chip are distributed in the same general way, we suggest that the Lebesgue norm of stress invariants in Eq. (120f) may be reasonably uniform. On physical grounds it can be argued that  $A_1$  and  $A_2$  are positive; therefore the variation in  $\theta$  will tend to cancel that of  $\sqrt{J}$  since the former invariant is large when the latter one is small and vice-versa. (This cancellation of effects will not occur with compression since both invariants increase algebraically with radius.) If indeed  $g'$ , and therefore  $a_G$ , are essentially independent of radius, the relation between average stress and axial strain will be essentially the same as for linear theory except  $\sigma/a_G$  will replace stress; this can be shown by referring to the thickness-averaged field equations for the poker-chip [19].

Hence, by making the substitution  $P \rightarrow \sigma/a_G$  in Eq. (125), the approximate equation with microcracking is obtained. That this equation successfully predicted recovery from creep would seem to imply  $a_G$  is essentially independent of time, although it depends on stress in view of the observed stress-dependence of creep compliance. For the power-law distribution function Eq. (111), we find during creep ( $0 < t < t_c$ ):

$$\frac{1}{a_G} = 1 + C_1(\sigma)^{r-1}(t)^q \quad (128)$$

where  $C_1$  is a constant; during recovery  $a_G^{-1}$  is given by Eq. (128) with  $t = t_c$ . For the data in Fig. 10,  $n \approx 1/6$ , which implies  $q \approx 14$ . Moreover, we find the stress-dependence of the creep compliance in Fig. 10 can be predicted by neglecting the unity term in Eq. (128) and setting  $r \approx 1.8$ . Thus, the time-dependence of  $a_G$  is relatively weak compared to that of the creep compliance itself. It is of interest to note in passing that the value  $r = 2$  is predicted from an approximate distribution function for strain concentration factors derived by Farr's [19] for spherical particles.

Strip-biaxial and uniaxial tests: A large number of constant strain rate tests were conducted at room temperature and at approximately  $-20^\circ\text{F}$  in order to assess the accuracy of simplified constitutive equations in Sections II-A and II-D.

Although most of the tests were conducted on ANB-3335-1 propellant, a study of ANB 3066 at  $T = -20^\circ\text{F}$  was made early in the program; typical results for stress and dilatation are shown in Fig. 19. The prediction of dilatation was made by first evaluating the constants  $a_g$  and  $b_g$  in the

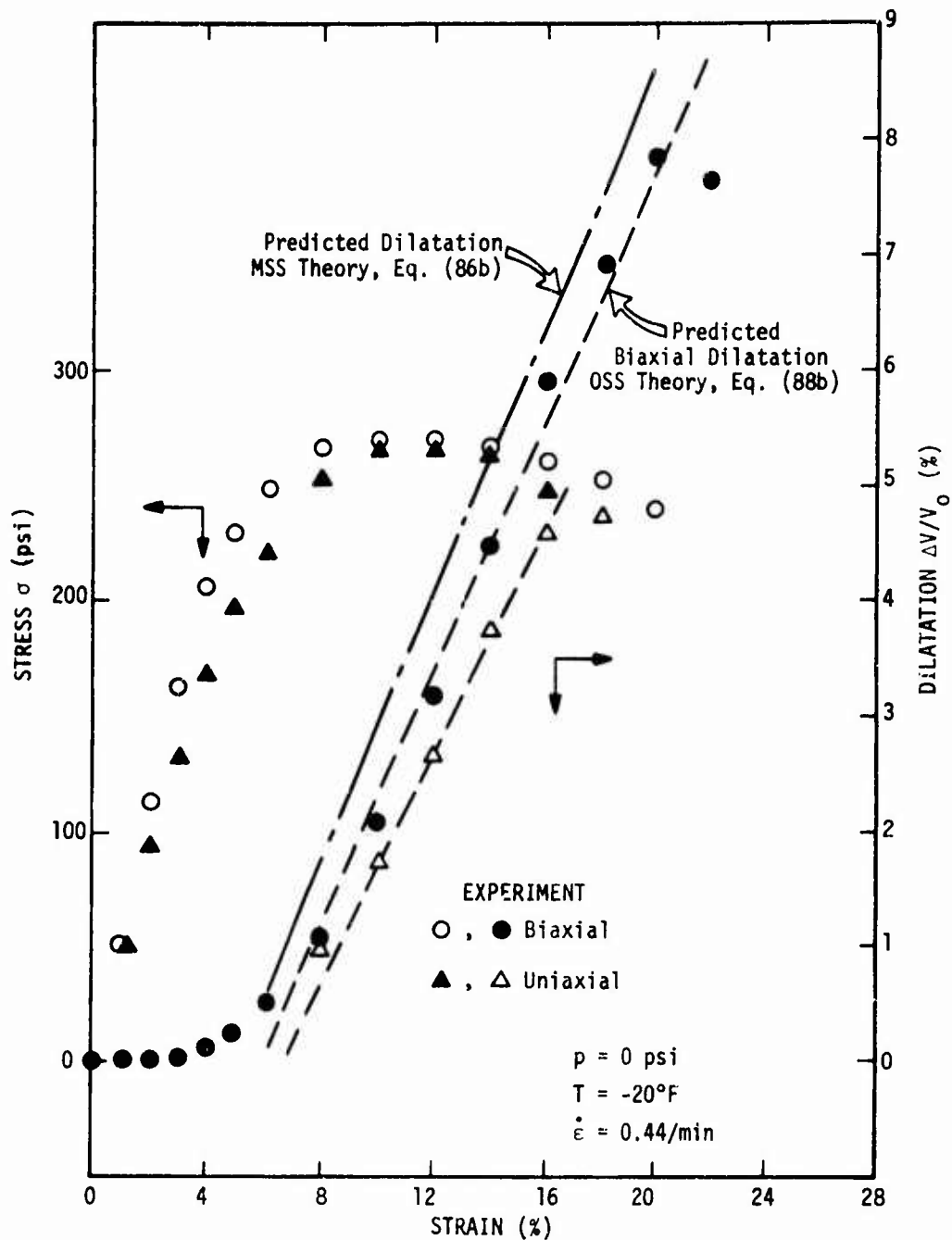


Figure 19. Uniaxial and Strip-Biaxial Data on ANB 3066 Propellant.

MSS theory and  $a$  and  $b$  in the OSS theory from the uniaxial data. Equations (86b) and (88b) were then used to construct the dilatation for the biaxial test. Obviously, the octahedral strain theory is most accurate for these data. Also, referring to Eq. (32), we find if  $\beta = 2$  the stress can be predicted reasonably well.

Similar results were found for ANB 3335-1, as shown in Fig. 20. Again the OSS theory is seen to be better than the MSS theory. Also, for this case  $\beta = 2$ . Typical room temperature data on this propellant are given in Fig. 21, for which  $\beta = 2.5$ . The biaxial dilatation data now fall between the OSS and MSS theories. A study of the data obtained on several other specimens revealed that the OSS prediction was generally best, although some of the results were similar to that shown in Fig. 21. In most of these latter cases some of the uniaxial specimens cut from a single strip appeared to fail prematurely, which would account for the OSS prediction being low compared to the biaxial dilatation data.

In order to check the hypothesis that  $\tilde{I}_3$  is absent from the dilatational constitutive Eq. (10) (or Eq. (61)), it is not, of course, necessary to use a piecewise linear representation of dilatation. If the term  $\theta/3K_e$  is negligible in these equations, then a plot of the actual uniaxial and biaxial data on a graph of  $I_T$  vs.  $\sqrt{I_2}$  will form a single curve if  $\tilde{I}_3$  does not enter the constitutive equation. Figures 22-25 show such plots for 0 psi and 200 psi. Although there is some spread, the theory seems to be quite adequate for correlating the dilatation in the biaxial and uniaxial modes; most of the spread is believed due to premature failure of some uniaxial samples.

It should be added that in view of the relatively large strains involved, we have used invariants based on Lagrangian strains in Figs. 22-25; see

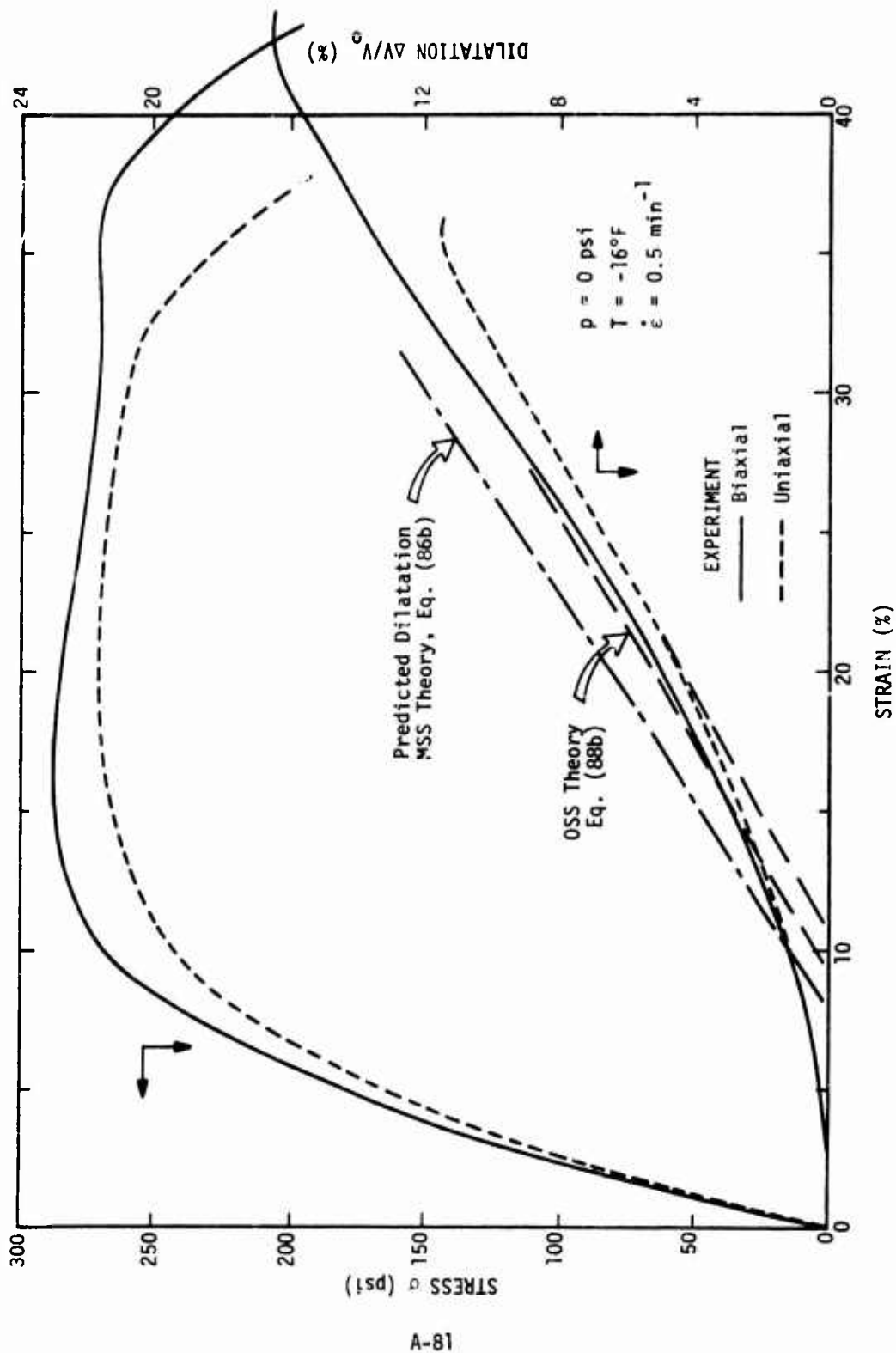


Figure 20. Uniaxial and Strip-Biaxial Data on ANB 3335-1 Propellant.

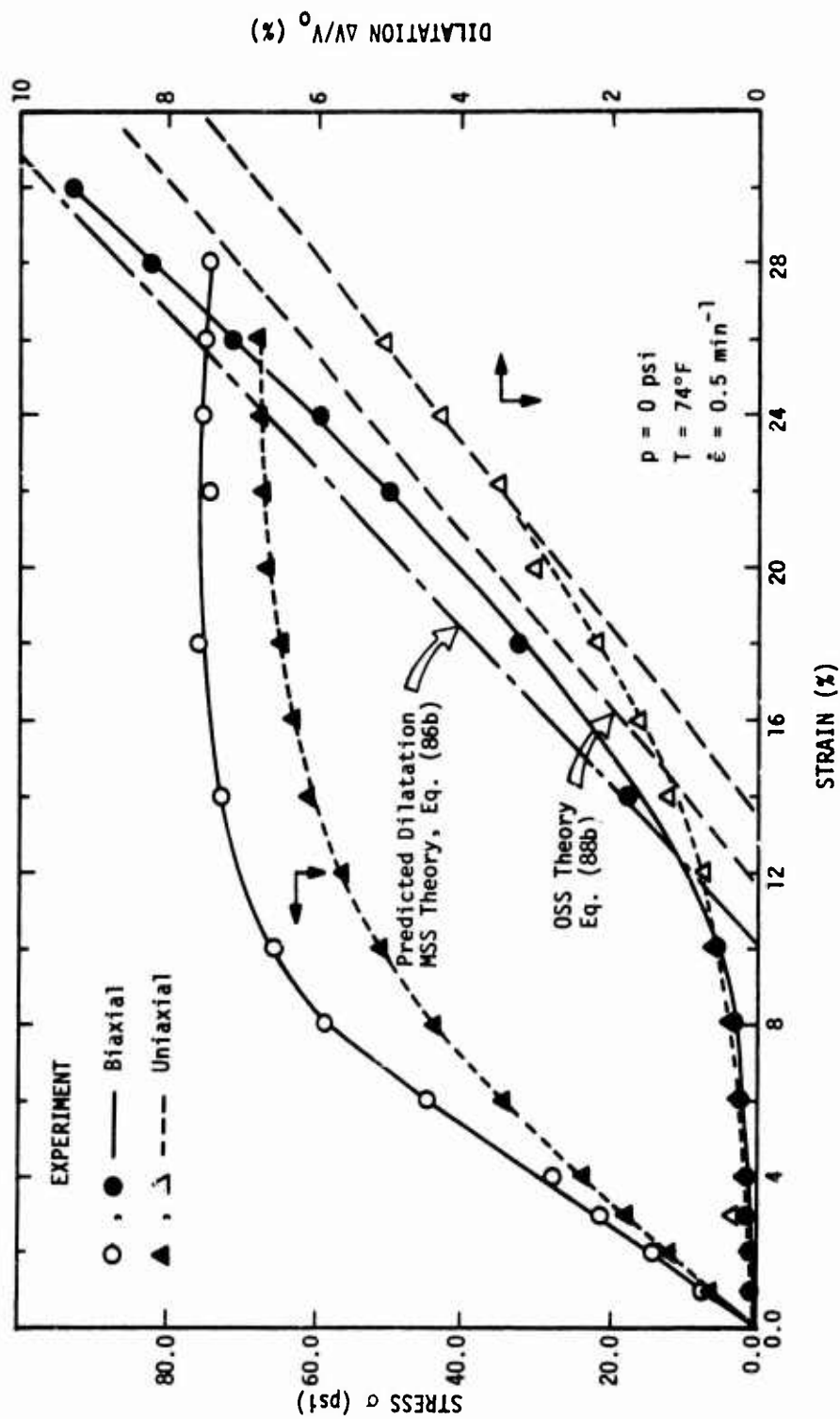


Figure 21. Uniaxial and Strip-Biaxial Data on ANB 3335-1 Propellant.

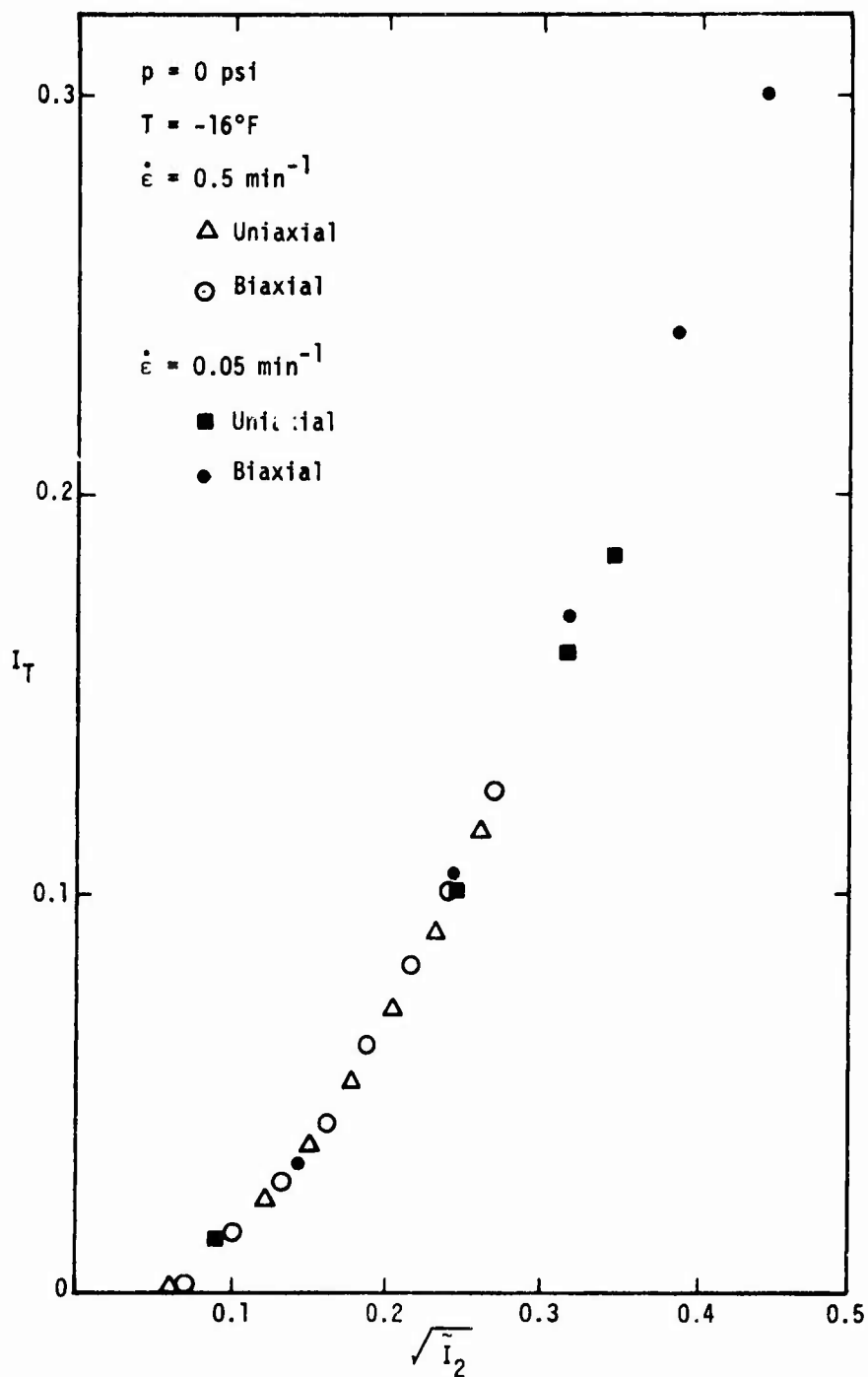


Figure 22. Relation Between First and Second Strain Invariants for Data in Fig. 20.

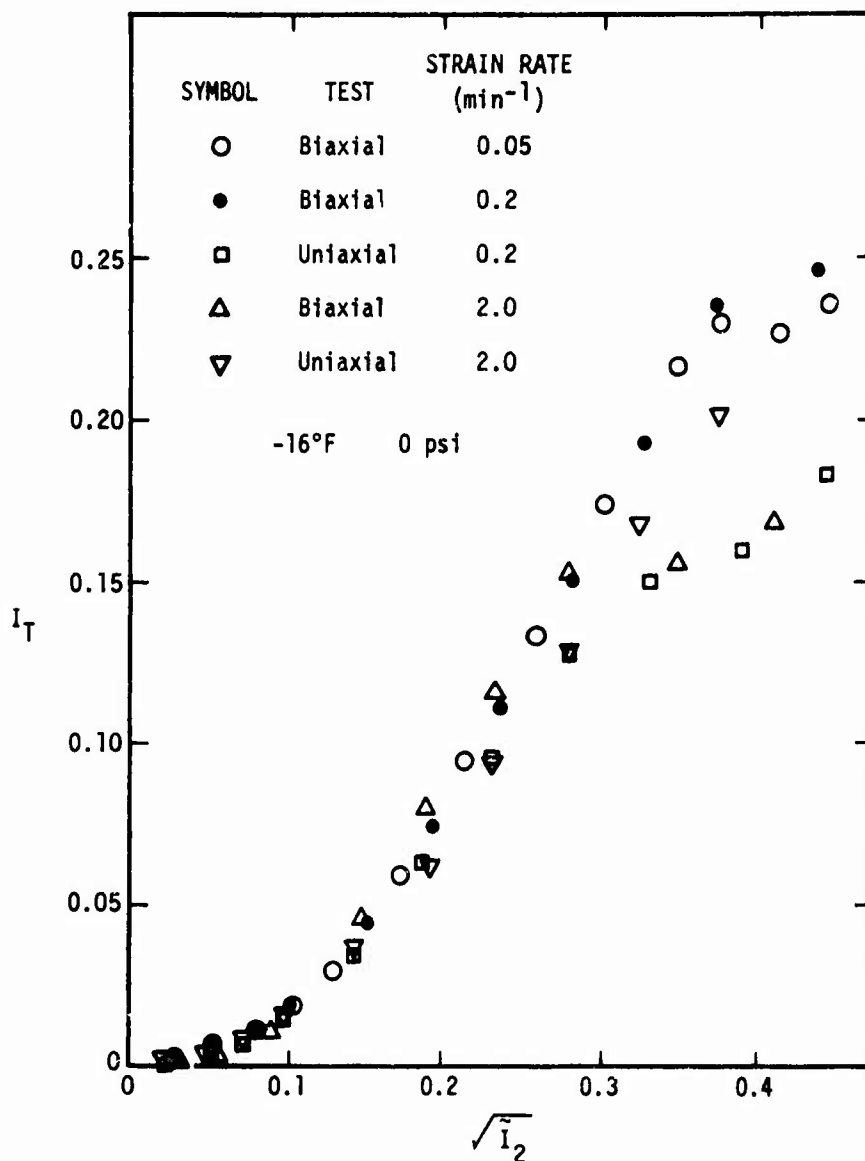


Figure 23. Relation Between First and Second Strain Invariants  
for ANB 3335-1 Propellant

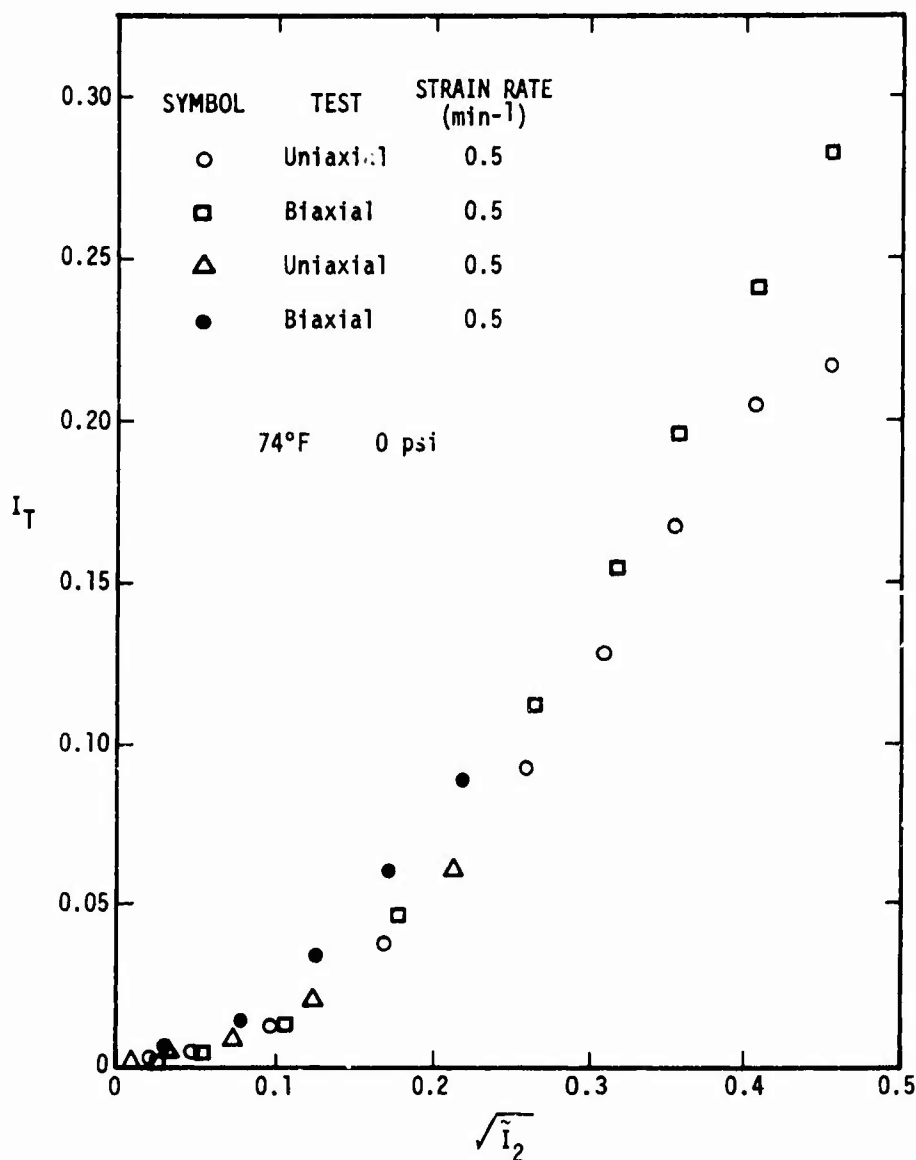


Figure 24. Relation Between First and Second Strain Invariants  
for ANB 3335-1 Propellant

A-85

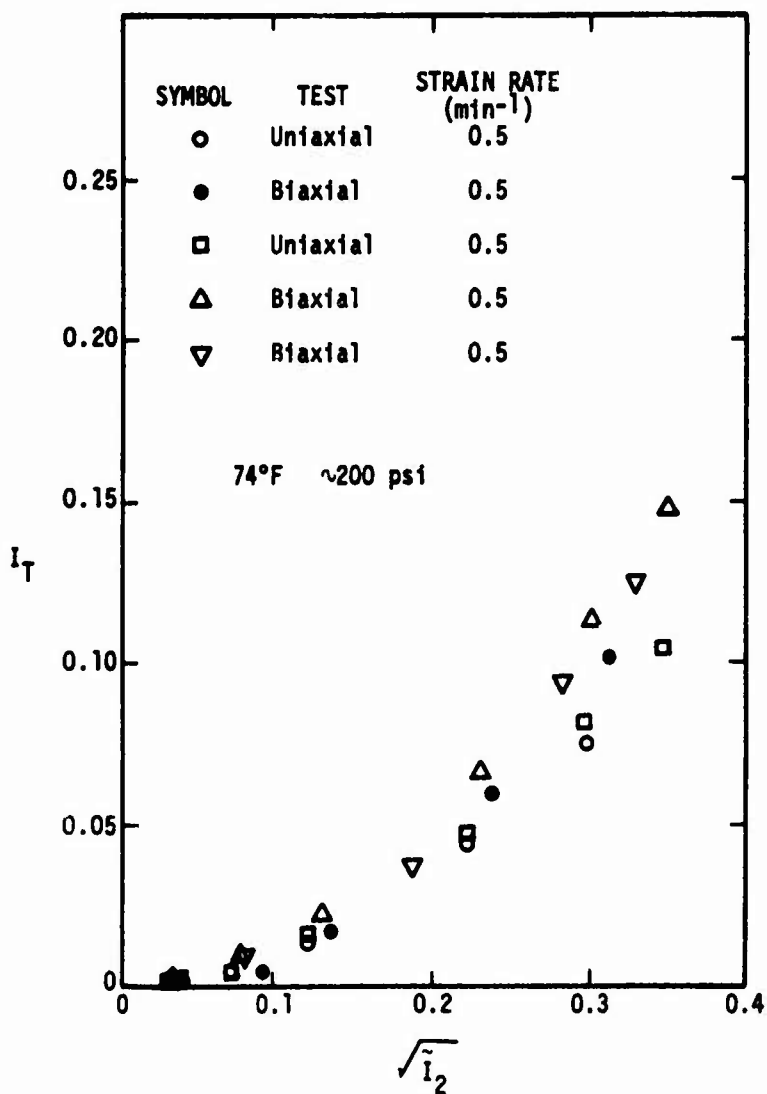


Figure 25. Relation Between First and Second Strain Invariants for ANB 3335-1 Propellant.

Section II-G. In particular, with primes denoting deviatoric strains,

$$I_T \equiv E_{11} - 3\alpha\Delta T \quad (129a)$$

$$\bar{I}_2 \equiv E_{ij}' E_{ij}' \quad (129b)$$

Note that the invariant defined by Eq. (129a) is not equal to the dilatation, except for small strains.

Finally, it is of interest to compare the value of the modulus ratio in Eq. (23) found from the uniaxial and biaxial stress-strain data with that obtained from the poker chip tests. For the former tests at 74°F we have found that the relation  $\beta/a \approx 5$  holds. Thus,

$$\frac{K_e}{G_e} \approx 5\sqrt{6} \approx 12 \quad (130)$$

Referring to Fig. 18, it is found that this result predicts the dilatation-strain ratio

$$\frac{\Delta V}{V_0 \epsilon} \approx 0.69 \quad (131)$$

where the standard linear elastic relation

$$G_e = \frac{3K_e E_u}{9K_e - E_u} \quad (132)$$

has been used; also, corresponding to the notation in Fig. 18,  $K_e \equiv K$ . The ratio in Eq. (131) is of the correct order of magnitude, based on the poker chip data in Fig. 12.

#### IV. CONCLUSIONS

Emphasis in this study has been on (i) establishing a simple constitutive theory for propellant at large values of vacuole dilatation, and (ii) the use of viscoelastic fracture mechanics as a means of relating overall mechanical response to fundamental parameters that define the extent of microstructural damage.

Under item (i) we have found the dilatation of strip-biaxial specimens and uniaxial specimens to be essentially equal when referred to equal values of the octahedral shear strain. An implication of this result is that the third deviatoric strain invariant probably can be omitted from the nonlinear constitutive theory without introducing appreciable error. It is shown that dilatation measured on thin simple shear specimens would provide another check of this conclusion; however shear data were not obtained in this study.

In the area (ii) we developed a constitutive theory which is identical to linear viscoelasticity except the stress tensor is multiplied by a scalar function that reflects microstructural damage. This function depends on a weighted Lebesgue norm involving stress invariants (rather than strain invariants) and is expressed in terms of temperature-reduced time; the weighting function in the norm reflects one effect of aging and rehealing, if any. The fracture mechanics theory was developed during the latter portion of the program and therefore only a limited check of the theory is given.

#### ACKNOWLEDGMENT

The author is indebted to Messrs. L. E. Lewis and R. T. Shankle who conducted most of the tests, and to Mr. J. B. Hattox who assisted during the latter phases of the study and prepared Section III-A. Mr. Scott W. Beckwith provided guidance on the experimental program during the course of the investigation, and his help is gratefully acknowledged.

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## APPENDIX B

### PREPROCESSOR CODE NL001

#### 1.0 INTRODUCTION

NL001 is a preprocessor for the nonlinear viscoelastic characterization code NL002. It takes the raw test data, consisting of a temperature, strain rate, time step increment, stress and dilatation, and then calculate the following data:

1. Principal strains, shear strain and true stress
2. Strain rates
3. Strain invariants
4. Dilatation, corrected for pressure and temperature
5. Octahedral strain
6. The 10th, 20th, 30th, 40th, 50th, 60th and infinite Lebesgue norms

All these data are generated for the same time points as the original data. The generated and raw test data are then assigned a user prescribed identification and written out onto a tape as a single element. This process is then repeated once for each test, with each test being limited to 100 input data points. There is, however, no limit to the number of tests which may be processed in a single run.

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## 2.0 PROGRAM INSTRUCTIONS

The purpose of this section is to list the basic variables of the NL001 code and provide a set of input instructions for running the program.

### 2.1 BASIC VARIABLES

Following is a list of the basic program variables of NL001. Each variable is described briefly and labeled as either an input or calculated output variable. All input is also saved as output. Any variable which is not either input or output is merely a working variable used internally, usually for intermediate calculations.

A1, A2	Working variables
BETA	Volumetric expansion coefficient - input
BULK	Bulk modulus - input
C1, C2	Arbitrarily small constants - fixed in program by user. Presently 1.0E-6.
DIL	Dilatation an input - corrected for temperature and pressure for output
DR1, DR2, DR12	Normal and shear calculated strain rates - output
DT	Time step in minutes - input
EOCT	Octahedral strain - output
EPS	Epsilon tester working variable
E11, E22, E33	Normal strains - output
E12	Shear strain - output
INV1	First strain invariant = $E_{11} + E_{22} + E_{33}$ - output
INV2	Second strain invariant = $E_{11} E_{22} + E_{22} E_{33} + E_{33} E_{11}$ - output

INV3	Third strain invariant = $E_{11} E_{22} E_{33}$ - output
KODE	Input control variable: = 1 if a uniaxial test, = 2 if a biaxial test, = 3 if a shear test
KTEMP	Input control variable: = 1 if a constant temperature test = 2 if a variable temperature test
LAST	Input delimiter flagging last input data point. Set blank or zero if not last data point - nonzero if last data point.
MATID	Material identification - input
NAME	Test identification - input
NDP	Number of data points of a specific test
NORMF	Infinite Lebesgue norm - output
NORMI	i-th Lebesgue norm - output
PRES	Test pressure - input
RATE	Strain rate, observed - input
SP	Working variable
STRESS	Observed stress-input
STRUE	True stress - output
T	Time in minutes - output
TEMP	Test temperature - input

## 2.2 INPUT INSTRUCTIONS

The following series of cards are read once for each test processed through NL001. The last card of the input deck is always a blank, however there is no blank card between tests. The required input variables for each card appear below with their formats shown in parentheses.

Card 1 (A6, E14.4, 2I5, 5a4, 2E15.6) NAME, PRES, KTEMP, KODE, MATID, BULK, BETA

Card(s) 2 (5E10.3, I5) TEMP(J), RATE(J), DT(J), STRESS(J), DIL(J), LAST

Here J indicates the Jth data point of this test. Card 2 is repeated once for each data point.

Cards 1 and 2 are repeated once for each test processed.

Card 3 - A blank card indicating that last test has been processed.

### 2.3 SAMPLE INPUT SHEET

Shown below is a sample input sheet for NL001. It contains the input data for two uniaxial constant temperature tests. The first, U00100 is at ambient pressure while U10105 is run at 100 psig.

### 2.4 PROGRAM LISTING

The listing of NL001 appears below. Note that it is written specifically for the UNIVAC 1108 computer. Use of this program on any other computer would require substitution of the appropriate statements for the MAKELT and SQUEEZ subroutines.



51 JUN 73 09:24:50 PAGE 10

6Y FOR M001, M002

DATE, TIME, LEVEL OF OUTPUT ELEMENT: 15 MAR 73 09:00:00

104100 43 73437 1 JMT 1 631MO  
FEBRUARY 1963 155510 2 6

51 JUN 73 09:24:50 PAGE 10

00:00:00 00:00:00 00:00:00

DATE 08-08-2014

## STORAGE USED (BLOCK, NAME, LENGTH)

0001	*CODE	001643
0000	*DATA	022565
0002	*HLANK	003800

## EXTERNAL REFERENCES (OLOCK - NAME)

0003	NTRAM
0004	EXIT
0005	NADUS
0006	NIOZS
0007	NIRCUS
0010	NICUS
0011	NERP2S
0012	CRAT
0013	SOMT
0014	OSGRT
0015	NEXPTS
0016	NSYOPS

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK)	TYPE	RELATIVE LOCATION	NAME
1	REAL	100	REAL
2	REAL	104	REAL
3	REAL	108	REAL
4	REAL	112	REAL
5	REAL	116	REAL
6	REAL	120	REAL
7	REAL	124	REAL
8	REAL	128	REAL
9	REAL	132	REAL
10	REAL	136	REAL
11	REAL	140	REAL
12	REAL	144	REAL
13	REAL	148	REAL
14	REAL	152	REAL
15	REAL	156	REAL
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30	REAL	216	REAL
31	REAL	220	REAL
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107			

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0000	017555	30F	0001	001755	30F	0001	017663	301F	0001	001777	31L	0001	000767	311F
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0001	001124	3746	0001	000125	4L	0001	000220	41L	0001	001227	4226	0001	001206	4226
0001	001260	4376	0001	000231	5L	0001	001436	5066	0001	001650	5176	0001	000306	612L
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0000	017505	N	0000	017541	NAMF	0000	017550	N8F	0000	017527	N2ND	0000	002711	00RFE0
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VACUJ, 025772.1, 100

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00145 65* NORM1(J) = 0.00
00147 66* NORM2(J) = 0.00
00150 67* NORM3(J) = 0.00
00151 68* NORM4(J) = 0.00
00152 69* NORM5(J) = 0.00
00153 70* NORM6(J) = 0.00
00154 71* RATE(I) = 0.0
00155 72* STRESS(I) = 0.0
00156 73* STRUE(I) = 0.0
00157 74* TTT = 0.0
00160 75* TEMP(I) = 0.0
00161 76* 100 CONTINUE
00163 77* J = 2
00164 78* REAN(5,3), NAME, PRES, KTEMP, KONE, (MATID(I), I=1,5), RULK, REFA
00164 79* C ALL NONE?
00164 80* C
00164 81* C
00200 82* IF (KONE.NE.0) GO TO 4
00202 83* CALL NTRANINU, 1, 10, NEND, LG)
00203 84* CALL NTRANINU, 9)
00204 85* CALL EXIT
00204 86* C
00204 87* C
00205 88* C
00206 89* CONTINUE
00207 90* J = J + 1
00217 91* REAN(5,1) TEMP(J), RATE(J), DT(J), STRESS(J), DIL(J), LAST
00217 92* IF (LAST.EQ.0) GO TO 4
00221 93* NMP = J
00222 94* DT(2) = 20.
00223 95* IF DT(2) = TEMP(3)
00224 96* TEMP(1) = TEMP(2)
00224 97* C
00224 98* C
00224 99* C
00225 100* LIST INPUT DATA.
00242 101* WRITE(6,30) NAME, NMP, PRES, KTEMP, KONE, (MATID(I), I=1,5), RULK, REFA
00242 102* 30 FORMAT(1H '-', T13, A6, T20, T35, F8.0, T50, T13, T60, T13, T70, 5A6,
00243 103* 1 T100, E10.4, T115, E10.4 )
00244 104* LINF = LINF + 1
00246 105* IF (LINF.LT.50) GO TO 41
00247 106* IPG = IPG + 1
00247 106* WRITE(6,24) IPG
00252 107* LINF = 0
00253 108* 41 CONTINUE
00253 109* C
00253 110* C
00254 111* C
00255 112* 5 GO TO(5,6,7)*KONE
00256 113* C COMPUTE STRAINS AND THE INVARIANT BASED ON TYPE OF TEST.
00257 114* CONTINUE UNIAxIAL TEST.
00257 115* NO 8 IE2, NMP
00262 116* DIL(I) = DIL(I)/100. - PRES/RULK
00263 117* SP = SP + RATE(I)*DT(I)
00264 118* E11(I) = 1 (1.0 + SP)**2 - 1.0 / 2.0
00265 119* DIL(I) = DIL(I) + C1*F1(I) + REFA*(TEMP(I)-TEMP(I)-1))
00266 120* E22(I) = ((1.0 + DIL(I))/(1.0 + SP)) - 1.0/2.0
00267 121* E33(I) = F22(I)
00270 122* 8 CONTINUE
00272 123* GO TO 10
00272 124* C

```



VMDATV4-N-5772.1.100

```

00354 1850 NORM20(I) = NORM20(I-1) + (A10021-A20021) / (210(A1-A2)DT(I))
00355 1860 NORM30(I) = NORM30(I-1) + (A10031-A20031) / (310(A1-A2)DT(I))
00356 1870 NORM40(I) = NORM40(I-1) + (A10041-A20041) / (410(A1-A2)DT(I))
00357 1880 NORM50(I) = NORM50(I-1) + (A10051-A20051) / (510(A1-A2)DT(I))
00360 1890 NORM60(I) = NORM60(I-1) + (A10061-A20061) / (610(A1-A2)DT(I))
00361 1900 GC TO 15
00362 1910 CO-TIME
00363 1920 NORM10(I) = NORM10(I-1) + (A10010-A20010)DT(I)
00364 1930 NORM20(I) = NORM20(I-1) + (A10020-A20020)DT(I)
00365 1940 NORM30(I) = NORM30(I-1) + (A10030-A20030)DT(I)
00366 1950 NORM40(I) = NORM40(I-1) + (A10040-A20040)DT(I)
00367 1960 NORM50(I) = NORM50(I-1) + (A10050-A20050)DT(I)
00370 1970 NORM60(I) = NORM60(I-1) + (A10060-A20060)DT(I)
00371 1980 CO-TIME
00373 1990 DO 27 I=1, NDP
00376 2000 NORM10(I) = NORM10(I) * (1./10.)
00377 2010 NORM20(I) = NORM20(I) * (1./20.)
00400 2020 NORM30(I) = NORM30(I) * (1./30.)
00401 2030 NORM40(I) = NORM40(I) * (1./40.)
00403 2040 NORM50(I) = NORM50(I) * (1./50.)
00404 2050 NORM60(I) = NORM60(I) * (1./60.)
00406 2060 CONTINUE
00407 2070 C 17
00408 2080 CO-TIME
00409 2090 C
00410 2100 WRITE OUT THE SINGLE PRECISION/INTEGER RECORD.
00412 2110 IF (LG+1) 300,31,32
00413 2120 CO-TIME
00414 2130 NOUT = 12 + 14*NDP
00415 2140 C
00416 2150 I=1) = NAME
00417 2160 I=2) = NPF
00418 2170 I=3) = PRFC
00419 2180 I=4) = KTEMP
00420 2190 I=5) = KODE
00421 2200 DO 19 K=1,5
00422 2210 J = K+5
00423 2220 I=J) = MATID(K)
00424 2230 R(1) = PULK
00425 2240 R(12) = RFTA
00426 2250 DO 20 I=1,10
00427 2260 N(I) = 12 + (I-1)*NDP
00428 2270 C
00429 2280 DO 21 I=1,NDP
00430 2290 J = N(I)
00431 2300 R(J+1) = TEMP(I)
00432 2310 J = R(2)
00433 2320 R(J+1) = RATE(I)
00434 2330 J = N(3)
00435 2340 R(J+1) = DT(I)
00436 2350 J = N(4)
00437 2360 R(J+1) = STRESS(I)
00438 2370 J = N(5)
00439 2380 R(J+1) = DTL(I)
00440 2390 J = R(6)
00441 2400 R(J+1) = T(I)
00442 2410 J = R(7)
00443 2420 R(J+1) = F1(I)
00444 2430 J = N(6)
00445 2440 R(J+1) = F2(I)

```

VRONAY,4,25772,1,100

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00461 245* J = N(9)
00462 246* R(J+1) = F33(I)
00463 247* J = N(10)
00464 248* R(J+1) = F12(I)
00465 249* J = N(11)
00466 250* R(J+1) = STRUF(I)
00467 251* J = N(12)
00470 252* R(J+1) = DR1(I)
00471 253* J = N(13)
00472 254* R(J+1) = DR2(I)
00473 255* J = N(14)
00474 256* R(J+1) = DR12(I)
00475 257* 21 CONTINUE
00477 258* CALL NTRAN(NU,1,NOUT,R,LQ)
00477 259* C
00477 260* C WRITE OUT THE DOUBLE PRECISION RECORD.
00477 261* C
00500 262* 33 IF(LD+1) 300,33,34
00503 263* 34 CONTINUE
00504 264* NOUT = 10*NDP
00504 265* C
00505 266* DO 22 I=1,11
00510 267* 22 N(I) = (1-I)*NDP
00510 268* C
00512 269* DO 23 I=1,NDP
00515 270* J = N(I)
00516 271* DR(J+1) = INV1(I)
00517 272* J = N(2)
00520 273* DR(J+1) = INV2(I)
00521 274* J = N(3)
00522 275* DR(J+1) = INV3(I)
00523 276* J = N(4)
00524 277* DR(J+1) = NORMF(I)
00525 278* J = N(5)
00526 279* DR(J+1) = FOCI(I)
00526 280* C
00527 281* IF(TEMP.F0.2) GO TO 23
00531 282* NOUT = 22*NDP
00531 283* C
00532 284* J = N(6)
00533 285* DR(J+1) = NORM10(I)
00534 286* J = N(7)
00535 287* DR(J+1) = NORM20(I)
00536 288* J = N(8)
00537 289* DR(J+1) = NORM30(I)
00540 290* J = N(9)
00541 291* DR(J+1) = NORM40(I)
00542 292* J = N(10)
00543 293* DR(J+1) = NORM50(I)
00544 294* J = N(11)
00545 295* DR(J+1) = NORM60(I)
00546 296* 23 CONTINUE
00546 297* C
00550 298* CALL NTRAN(NU,1,NOUT,DR,LD)
00550 299* C
00550 300* C
00551 301* GO TO 2
00552 302* 300 CONTINUE
00552 303* C
00552 304* C TAPE WRITE ERROR

```

[illegible]

**CROSS REFERENCE BY SEQUENCE NUMBER**

SINGLE WORK, COLLERITH STRINGS-----  
 140 : 0107

[illegible]





## APPENDIX C

### POST PROCESSOR CODE

#### 1.0 INTRODUCTION

POST is a postprocessor for the NL001 code. It takes the output of NL001 off the NL001 output tape, and prints selected output in a report format. There is a minimum of two pages of output for each test reported. The first two columns of each page are the data point numbers and time in seconds. Page 1 then contains the three strain invariants, the dilatation  $\Delta V/V_0$ , corrected for any temperature and pressure effects, and the octahedral strain. Page 2 displays the temperature, calculated strains, and the true stress. In addition to the above, each page has a heading giving material type, bulk modulus and volumetric expansion coefficient, the test type, initial strain rate, pressure, and whether it is a constant or variable temperature test.

The only card input to POST is the last card, a blank, signifying the end of the data. All other input is read directly from the NL001 output data tape.

#### 2.0 PROGRAM INSTRUCTIONS

The purpose of this section is to list the basic variables of the POST code and provide a set of instructions for running the program.

##### 2.1 BASIC VARIABLES

Following is a list of the basic program variables of POST. The names and meaning of variables is compatible with the NL001 code.

BETA	Volumetric expansion coefficient
BULK	Bulk modulus
DUM	Dummy variable
EDOTO	Initial strain rate
ITEMP	Alphanumeric constant/variable temperature header
ITYPE	Alphanumeric uniaxial/biaxial/shear test type header
KODE	Test type control variable
KTEMP	Temperature control variable
LAST	Last data point delimiter
MATID	Material identification
NAME	Test element identification
NDP	Number of data points in a specific test
PRES	Test pressure, psig
X	An array used to store the various output quantities

## 2.2 INPUT INSTRUCTIONS

There is no card input for POST. All input is read from the NLOO1 data output tape, element by element. The user merely inserts an "ADD" card for each element of the tape he wishes processed by POST. After the last "ADD" card, the user inserts a blank card to terminate execution.

## 2.3 SAMPLE INPUT SHEET AND OUTPUT

Shown below is a typical input sheet for POST showing the UNIVAC 1108 "ADD" cards and the last (blank) card. In the example shown, two tests are processed U00100 and U10105. Following the sample input sheet is the actual output generated by POST.

2.4 The listing of POST appears below. Note that it is machine independent, except that it expects the input to be in a specific format. This format is exactly that used by the NL001 code.

JOB NUMBER

REPORT TITLE

Sample Input - Post

DATE

11 XGT POST

11 ADD 400100

11 ADD 410105

11 ( BLANK CARD )

Q ELT POST,1,730521, 48361

```

000001      C      POST-PROCESSOR FOR AL001.
000002      C
000003      C
000004      C      DIMENSION MATID(5), Y(7,100)
000005      C      DOUBLE PRECISION ITMP(2), ITYPE(3)
000006      C      DATA ITEM(1),CONSTANT,ITEMP(2),VARIABLE,ITYPE(1),UNITAXIAL,
000007      C      1,ITYPE(2),IGAXIAL,ITYPE(3),SHEAR,
000008      C
000009      C      NEXT TEST
000010      C
000011      C
000012      50 CONTINUE
000013      IPG = 0
000014      READ(5,A) NAME, PRES, KTEMP, KONF, (MATID(I),I=1,5),HULK,RETA
000015      C      IF (KONF.EQ.0) CALL EXIT
000016      IND = 0
000017      IPG = IPG + 1
000018      C      CONTINUE
000019      IND = IND + 1
000020      READ(5,9) X(2,IND), X(3,IND), LAST
000021      IF (LAST.EQ.0) GO TO 51
000022      F0000 = X(3,3)
000023      WRITE(6,1) NAME, NAME, IPG
000024      WRITE(6,2) (MATID(I),I=1,5), ITYPE(KONF)
000025      WRITE(6,3) HULK, EDOTO, RETA, PRES, ITEM(TEMP)
000026      WRITE(6,4)
000027      I = 1
000028      C      CONTINUE
000029      READ(5,10) X(1,1), X(3,1), X(4,1), X(5,1), X(6,1), X(7,1), LAST
000030      I = I+1
000031      IF (LAST.EQ.0) GO TO 52
000032      DO 100 I=2,IND
000033      C      CONVERT TIME FROM MINUTES TO SECONDS FOR PRINTOUT
000034      C
000035      C      X(1,I) = X(1,I)*60.
000036      K = I-1
000037      WRITE(6,5) K, (X(J,I),J=1,7)
000038      C      CONTINUE
000039      100 CONTINUE
000040      C
000041      C
000042      C
000043      53 CONTINUE
000044      READ(5,11) LAST
000045      IF (LAST.EQ.0) GO TO 53
000046      C
000047      C      IPG = IPG + 1
000048      WRITE(6,1) NAME, NAME, IPG
000049      WRITE(6,2) (MATID(I),I=1,5), ITYPE(KONF)
000050      WRITE(6,3) HULK, EDOTO, RETA, PRES, ITEM(TEMP)
000051      WRITE(6,6)
000052      C
000053      I = 0
000054      C      CONTINUE
000055      I = I+1
000056      READ(5,12) X(2,1), X(3,1), X(4,1), NUM, X(5,1), X(6,1), LAST
000057      IF (LAST.EQ.0) GO TO 54
000058      C
000059      C
000060      C
000061      C
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VRONAY,425772.1,100

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000057 C
000058 C
000059 NO 200 I=2,NDP
000060 K = I-1
000061 WRITE(6,7) K, (X(J,I),J=1,6)
000062 200 CONTINUE
000063 C
000064 C
000065 C
000066 55 CONTINUE
000067 READ(5,13) LAST
000068 IF(LAST.EQ.0) GO TO 55
000069 C
000070 C
000071 GO ON TO NEXT TEST
000072 GO TO 50
000073 C
000074 C
000075 1 FORMAT(1H,140,'S U M M A R Y O F T E S T N O .',A6,
000076 1 T113,'PAGE',A6,'-',I2,'/',T10,'M A T E R I A L',
000077 2 'D A T A',T95,'T E S T D A T A',/)
000078 2 FORMAT(1H, T10,'MATERIAL IS',A54,T95,'TYPE ...',A8)
000079 3 FORMAT(1H, T10,'BULK MODULUS =',F10.4,T95,'INITIAL STRAIN',
000080 1 'RATE =',F10.4,/, T10,'VOLUME',T95,'EXPANSION COEFFICIENT',
000081 2 ' =',F10.4,T95,'PRESSURE =',F10.0,/, T95,
000082 3 'TEMPERATURE IS',A8)
000083 4 FORMAT(1H, ///,T10,'DATA',T23,'TIME',T37,'TEMP',T72,'STRAIN',
000084 1 ' (CALCULATED)',T117,'TRUE STRESS',T110,'POINT',T23,
000085 2 'SEC',T37,'DEG-F',T56,'E1',T71,'E22',T86,'E3',T101,
000086 3 'E12',T117,'(S11 - S22)',/)
000087 5 FORMAT(1H, T10,'T10,F10.3,T33,'E10.4,T47,'E15.4,T112,'E15.4)
000088 6 FORMAT(1H, ///,T10,'DATA',T23,'TIME',T52,'STRAIN INVARIANTS',
000089 1 T92,'CORRECTED',T112,'OCTAHEDRAL',T110,'POINT',T23,
000090 2 'SEC',T47,'E1',T62,'E2',T77,'E3',T92,'OILATATION',
000091 3 T114,'STRAIN',/)
000092 7 FORMAT(1H, T10,'T10,F10.3,T37,'F15.4,T92,'F10.4,T112,'E10.4)
000093 8 FORMAT(A6,F10.4,215,5A4,2E15.6)
000094 9 FORMAT(2F10.3,30X,15)
000095 10 FORMAT(6F12.4,1P)
000096 11 FORMAT(60X,110)
000097 12 FORMAT(6E12.5,18)
000098 13 FORMAT(72X,18)
000099 FND

```

00:00:07.106

3. III A

END OF FILE -- UNIT A

END CUR, ISD VERSION 2.12

VRONAY-425772-1-100

22 MAY 73 10:50:14 PAGE 7

S U M M A R Y O F T E S T N O . 000100

PAGE 100100 - 3

M A T E R I A L D A T A

MATERIAL IS ANO 3335-1  
 BULK MODULUS = .5000+06  
 VOLUME TRIC EXPANSION COEFFICIENT = .1000-03

T E S T D A T A

TYPE ... UNIAxIAL  
 INITIAL STRAIN RATE = .5000+00  
 PRESSURE = 0. PSIG  
 TEMPERATURE IS CONSTANT

DATA POINT	TIME SFC.	TEMP. DEG.-F	F11	F22	STRAINS (CALCULATED) E11	E12	TRIF STRESS (S11 - S22)
1	.000	150.	.0000	.0000	.0000	.0000	.0000
2	.540+01	150.	.4601-01	-.2153-01	-.2153-01	.0000	.151+02
3	.840+01	150.	.7245-01	-.3224-01	-.3224-01	.0000	.2321+02
4	.114+02	150.	.9051-01	-.4178-01	-.4178-01	.0000	.2051+02
5	.144+02	150.	.1272+00	-.5000-01	-.5000-01	.0000	.2324+02
6	.174+02	150.	.1555+00	-.5677-01	-.5677-01	.0000	.2500+02
7	.204+02	150.	.1845+00	-.6261-01	-.6261-01	.0000	.2578+02
8	.234+02	150.	.2140+00	-.6709-01	-.6709-01	.0000	.2563+02
9	.264+02	150.	.2442+00	-.7205-01	-.7205-01	.0000	.2538+02
10	.294+02	150.	.2750+00	-.7771-01	-.7771-01	.0000	.2486+02

VRONAY.4.5772.1.100

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PAGE 100100 - 2

SUMMARY OF TEST NO. 100100

MATERIAL DATA

MATERIAL IS AND 3335-1  
HULK MODULUS = 5000+06  
VOLUME FRICTION EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... INITIAL STRAIN RATE = .5000+08  
PRESSURE = 0. PSIG  
TEMPERATURE IS CONSTANT

C-8

DATA POINT	TIME SEC.	STRAIN INVARIANTS			CORRECTED DILATATION	OCTAHEDRAL STRAIN
		I1	I2	I3		
1	.000	.0000	.0000	.0000	.0000	.0000
2	.500+01	.2950-02	-.1518-02	.2133-04	.4601-07	.3184-01
3	.800+01	.7964-02	-.3632-02	.7532-04	.1000-02	.4036-01
4	.114+02	.1595-01	-.6570-02	.1737-03	.3500-02	.6661-01
5	.144+02	.2720-01	-.1022-01	.3180-03	.0000-02	.8551-01
6	.174+02	.4168-01	-.1443-01	.5012-03	.1500-01	.1001+00
7	.204+02	.5924-01	-.1918-01	.7230-03	.2350-01	.1165+00
8	.234+02	.7803-01	-.2448-01	.9893-03	.3950-01	.1326+00
9	.264+02	.9830-01	-.3031-01	.1300-02	.4200-01	.1895+00
10	.294+02	.1196+00	-.3670-01	.1661-02	.5150-01	.1663+00

END 010105

22 MAY 73 10:40:10 PAGE 1

# Summary of Test Results

## Material Data

MATERIAL IS AIR 3335-1  
 RULS EQUILIB = 5000+00  
 VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

## Test Data

TYPE ... UNIAxIAL  
 INITIAL STRAIN RATE = .5000+00  
 PRESSURE = 100. PSI  
 TEMPERATURE IS CONSTANT

DATA POINT	TIME SFC.	TEMP. DEG.-F	F11	F22	STRAINS (CALCULATED) F33	E12	TRUE STRESS (S11 - S22)
1	.000	150.	-.6666-04	-.6666-04	-.6666-04	.0000	.0000
2	.390+01	150.	.3296-01	-.1500-01	-.1500-01	.0000	.1057+02
3	.690+01	150.	.5000-01	-.2722-01	-.2722-01	.0000	.1004+02
4	.990+01	150.	.6583-01	-.3805-01	-.3805-01	.0000	.2780+02
5	.129+02	150.	.1132+00	-.4832-01	-.4832-01	.0000	.2508+02
6	.159+02	150.	.1412+00	-.5808-01	-.5808-01	.0000	.4302+02
7	.189+02	150.	.1698+00	-.6732-01	-.6732-01	.0000	.5066+02
8	.219+02	150.	.1991+00	-.7609-01	-.7609-01	.0000	.5865+02
9	.249+02	150.	.2289+00	-.8444-01	-.8444-01	.0000	.6111+02
10	.279+02	150.	.2594+00	-.9241-01	-.9241-01	.0000	.6482+02
11	.309+02	150.	.2906+00	-.1001+00	-.1001+00	.0000	.6885+02
12	.321+02	150.	.3032+00	-.1030+00	-.1030+00	.0000	.6671+02

VRONAY, 4.5/72.1.100

22 MAY 73 10:50:14 PAGE 10

PAGE U10105 - 2

SUMMARY OF TEST NO. U10105

## MATERIAL DATA

MATERIAL IS ANR 335-1

BULK MODULUS = .5000+06

VOLUME THERMAL EXPANSION COEFFICIENT = .1800-03

## TEST DATA

TYPE ... UNIAXIAL

INITIAL STRAIN RATE = .0000+00

PRESSURE = 100. PSIG

TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	11	STRAIN INVARIANTS I2	13	CORRECTED DILATATION	OCTAHEDRAL STRAIN
1	.900	-.2000-03	.1333-07	-.2063-12	-.2000-03	.1054-07
2	.390+01	.1351-02	-.7920-03	.8232-05	-.2000-03	.2200-01
3	.600+01	.4636-02	-.2476-02	.4376-04	-.2000-03	.4060-01
4	.990+01	.9748-02	-.5083-02	.1242-03	.7009-04	.5040-01
5	.120+02	.1655-01	-.8606-02	.2644-03	.4001-03	.7616-01
6	.150+02	.2505-01	-.1303-01	.4762-03	.9061-03	.6300-01
7	.180+02	.3510-01	-.1833-01	.7696-03	.1400-02	.1118+00
8	.219+02	.4690-01	-.2450-01	.1152-02	.2500-02	.1207+00
9	.240+02	.6007-01	-.3153-01	.1632-02	.3530-02	.1477+00
10	.270+02	.7463-01	-.3041-01	.2215-02	.4460-02	.1650+00
11	.300+02	.9047-01	-.4813-01	.2909-02	.5020-02	.1841+00
12	.321+02	.9714-01	-.5186-01	.3218-02	.6270-02	.1015+00

DATA CARDS IGNORED - FIRST IS LISTED BELOW

## APPENDIX B

### CHARACTERIZATION CODE NL002

#### 1.0 INTRODUCTION

The computer code NL002 is a nonlinear thermoviscoelastic characterization code that accepts pressurized uniaxial, biaxial and shear data from code NL001. Dozens of experiments of this type having arbitrary deformation-temperature time histories can be simultaneously fit to constitutive equations using NL002 which performs both a distortional and bulk characterization as described in the text of this report.

#### 2.0 PROGRAM INSTRUCTIONS

The purpose of this section is to present the basic program variables, their definitions and use in the NL002 code, a sample problem and a listing of the program following the sample problem input sheet.

##### 2.1 BASIC VARIABLES

A	Coefficient in $e^{A \cdot DIL/EOCT}$ which is a modulus multiplier
AT	Shift function - input
AVGAT	Interpolated value of shift function at a specific arbitrary point
B	Coefficient of $t$ in power law term $(1 + Bt)^P$ - input
BB	Solution vector in regression analysis
BCAL	Calculated value of dilatational stress
BETA	Thermal volumetric expansion coefficient - input
BO	Regression coefficients for bulk term - calculated
BULK	Bulk modulus - input
CO	Regression coefficients for shear term - calculated
D	Slope of shift function vs temperature curve - calculated
DEV	Local percent error

DEV1      Final local error on  $\sigma_{11}$   
 DEV2      Final local error on  $\sigma_{22}$   
 DI        Working variable  
 DIL        Corrected dilatation  $\Delta V/V_0$  - input  
 DR1        Calculated strain rate  $\dot{E}_{11}$  - input  
 DR2        Calculated strain rate  $\dot{E}_{22}$  - input  
 DR12      Calculated strain rate  $\dot{E}_{12}$  - input  
 DT        Time step - input  
 DTR        Reduced time step - calculated  
 EOCT      Octahedral strain - input  
 E11, E22, E33    Principal strains - input  
 E12        Shear strain - input  
 F        A coefficient defined as  $F = e^{[A \cdot DIL / E_{OCT}]}$   
 G        A coefficient defined as  $G = (1 - \frac{E_{OCT}}{NORMF})$   
 IFF        F coefficient flag; set IFF(I) = 1 to multiply Ith term in  
           regression by the coefficient F  
 IFG        G coefficient flag; set IFG(I) = 1 to multiply Ith power law  
           term by the coefficient G  
 IFN        Norm selector; selects up to six norm terms, 10th, 20th, 30th,  
           40th, 50th, or 60th depending upon whether or not IFN(I) is 1, 2,  
           3, 4, 5, or 6 respectively.  
 INT1, INT2,    Hereditary integral terms - calculated  
 INT12  
 INV1, INV2,    First, second, and third strain invariants respectively - input  
 INV3

IPG	Page counter
KODE	Test type indicator - input
KTEMP	Constant or variable temperature test indicator - input
LAST	Input data delimiter
LINE	Output line counter
MATID	Material identification - input
NAME	Run title printed at top of each page
NAT	Number of values of shift function vs temperature
NBULKS	Number of terms in series for bulk term regression presently fixed at 14
NDP	
NORM	The Lebesgue norms of $E_{OCT}$ - input
NORMF	Infinite norm of $E_{OCT}$ - input
NORMS	Number of norm terms in series for shear term regression - limited to a maximum of 6
NPL	Number of power law terms of the form $(HBt)^P$
NTERMS	Number of terms in series for shear term regression - limited to a maximum of 14.
NTEST	Test number in this run
NTOT	Total number of data points processed in this run, i.e., $\Sigma NDP$
N1	First data point used in regression analysis
P	Exponent in power law term $(HBt)^P$
PRES	Test pressure, psig
R	Primary matrix of regression analysis
RATE	Observed strain rate - input

RESID	
RESID1	Interim variable used in calculating standard deviations
RESID2	
SCAL	Calculated value of stress in shear regression
STD	Standard deviation
STRESS	Observed stress
STRN	Interim strain storage variable
STRUE	True stress
SUM	
SUM1	Interim variables used in calculating average error and standard deviation
SUM2	
S1, S2	True stress, $STRUE = S1 - S2$
S1CAL	
S2CAL	Calculated values of S1 and S2
T	Time in minutes
TEMP	Test temperature
TITLE	Test identification - input
TR	Reduced time - calculated
TSHFT	Temperature at which shift function is input
XBAR	Average error
XF, XF1, XF2	Terms in series used for regression analysis
XN	Power to which norm term is raised
XP, XQ	Working variables
Z	Exponent of G coefficient

## 2.2 PROGRAM INPUT

This section lists the required input for NL002 on a card by card basis. The format for each card is shown in parentheses.

- Card 1 (20A4) NAME
- Card 2 (2E10.0) A, Z
- Card 3 (7I5) IFG(I), I = 1,7
- Card 4 (14I5) IFF(I) I = 1, 14
- Card 5 (06I5) IFN(I), I = 1,6
- Card 6 (6E10.0) XN(Ie) I = 1,6
- Card 7 (15) NPL
- Card(s) (8E10) (P(I)), I = 1 NPL)
- Card(s) 9 (2E10.0, I5) TSMFT(I), AT(I), LAST. Where  
LAST = 0 or blank if another TSMFT vs AT pair follows, and  
LAST  $\neq$  0 if this is last pair.
- Card(s) 10 "ADD" cards to add elements from NL001 output data tape, as  
many as desired
- Card 11 A blank card to indicate end of data
- The above cards are shown on the coding sheet below.

## 2.3 SAMPLE PROBLEM

Shown below is an input sheet for a simple but typical problem using 13 tests of 77° data, as indicated in the title, Card 1. Card 2 sets A = Z = 1.0. Card 3 indicates that all power law terms are multiplied by G. Card 4 indicates that all terms in the shear term series are to be multiplied by F. Card 5 says to take 6 norm terms, but to use the 10th norm for each

term. Card 6 gives the power to which each norm term indicated on Card 5 is raised. Card 7 indicates how many power law terms to keep; here 3. Card 8 shows that these 3 power law terms of the for  $(1 + Bt)^j$  are  $(1 + t)$ ,  $(1 + 2t)^2$ , and  $(1 + 3t)^3$ . Card 9 shows a constant shift function vs temperature curve. Cards 10 are the elements from the NL001 data output tape for the tests of interest. Card 11 is a blank card which indicate the ned of a run.

#### 2.4 PROGRAM LISTING

A complete source listing follows the data input sheet for the above problem.





NL002 DEMONSTRATION PROBLEM

A = -.100+01  
Z = .100+01

POWER LAW TERMS, (1 + ReT)\*\* P

I	R(I)	P(I)	IFG(I)
1	1.000+10	-1.330-01	0
2	1.000+10	-2.660-01	0
3	1.000+10	-4.000-01	0
4	0.000	0.000	0
5	0.000	0.000	0
6	0.000	0.000	0
7	0.000	0.000	0

IFF(I)

I	IFF(I)
1	1
2	1
3	1
4	1
5	1
6	1
7	1
8	1
9	1
10	1
11	1
12	1
13	1
14	1

XN(I)

NORM

I	NORM	XN(I)
1	30	2.000+00
2	30	4.000+00
3	30	6.000+00
4	40	8.000+00
5	50	1.000+01
6	60	1.200+01

NL002 DEMONSTRATION PROBLEM

THERE WERE 10 VALUES OF SHIFT FUNCTION VS. TEMPERATURE ...

1	AT(I)	TSHIFT(I)
1	1.000+10	-9.000+01
2	1.000+08	-6.500+01
3	1.500+06	-4.000+01
4	6.000+04	-2.000+01
5	3.000+03	0.000
6	2.000+01	4.000+01
7	1.000+00	7.700+01
8	2.500-01	1.000+02
9	3.000-02	1.400+01
10	1.000-02	1.600+02

TEST NO.	TEST IN	NL 0 0 2 NDP	DEMONSTRATION CODE	KTFMP	PRESSURE	TEMP
1	U00300	20	1	1	.00	77.0
2	U00301	12	1	1	.00	77.0
3	U00302	16	1	1	.00	77.0
4	U00303	14	1	1	.00	77.0
5	U00304	13	1	1	.00	77.0

# NONLINEAR THERMOVISCOELASTIC CHARACTERIZATION CODE

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## NL002 DEMONSTRATION PROBLEM SUMMARY OF SHEAR TERM FOR TEST NO. 1

TIME	E11 OR E12	DV/DV0	STRIE	S-CALC	ERROR	XF(I), I=1, NTERMS	
77.0000	.0700	.0356	.0000	14.5600	17.5426	5.9334	.5250-01 .1084-03 .2239-06 .4625-00 .6730-12 .9678-15 .1380-17 .8038-02 .3175-04 .2535-04
77.0000	.1100	.0565	.0006	26.3671	27.8821	4.2666	.8223-01 .4022-03 .1969-05 .9637-08 .3826-10 .1203-12 .4102-15 .5947-02 .8805-03 .3309-04
77.0000	.1600	.0832	.0020	38.8094	38.9273	1.3379	.1191+00 .1182-02 .1178-04 .1167-06 .8638-09 .6311-11 .8577-13 .8195-02 .5773-04 .4125-04
77.0000	.2100	.1105	.0041	49.2874	48.9865	-1.4508	.1557+00 .2556-02 .4208-04 .6926-06 .8648-08 .1067-09 .1305-11 .1033-01 .7014-03 .8829-04
77.0000	.2600	.1384	.0083	57.6174	57.1875	-1.7861	.1916+00 .4603-02 .1110-03 .2676-05 .8968-07 .9113-09 .1658-10 .1235-01 .8105-04 .5444-04
77.0000	.3100	.1670	.0139	64.2351	63.3700	-1.3868	.2270+00 .7369-02 .2404-03 .7882-05 .1994-06 .5007-08 .1248-09 .1428-01 .9108-03 .6000-04
77.0000	.3600	.1962	.0210	68.3164	67.5813	-1.0760	.2620+00 .1086-01 .8532-03 .1891-04 .6211-06 .2015-07 .6487-09 .1615-01 .1010-02 .6515-04
77.0000	.4100	.2260	.0295	71.6129	70.2882	-1.0056	.2957+00 .1507-01 .7709-03 .3983-04 .1682-05 .6432-07 .2562-08 .1757-01 .1115-02 .6999-04
77.0000	.4600	.2564	.0388	73.8568	71.9841	-2.5356	.3314+00 .2002-01 .1221-02 .7432-04 .8623-05 .1745-06 .8337-08 .1977-01 .1208-02 .7471-04
77.0000	.5100	.2875	.0487	75.7367	73.4986	-2.4551	.3662+00 .2573-01 .1825-02 .1295-03 .7386-05 .4174-06 .2337-07 .2156-01 .1209-02 .7932-04
77.0000	.5600	.3192	.0595	77.0994	75.3544	-2.2114	.4010+00 .3209-01 .2506-02 .2100-03 .1377-04 .8913-06 .5725-07 .2332-01 .1388-02 .8376-04
77.0000	.6100	.3515	.0702	78.2113	77.6784	-1.6815	.4362+00 .3932-01 .3587-02 .3273-03 .2831-04 .1784-05 .1208-06 .2510-01 .1479-02 .8827-04

N L 0 0 2 D E M O N S T R A T I O N P R O B L E M  
SUMMARY OF SHEAR TERM FOR TEST NO. 1

TEMP	TIME	E11 OR E12	DV/V0	STRUE	S-CALC	ERROR	XF(I), I=1,NTEMP					
77.0000	.6600	.3844	.0815	79.0363	80.1442	1.4017	* .4715+00	.4721-01	.4790-02	.4859-03	.4933-04	.9264-04
							* .3306-05	.2649-06	.2646-01	.1564-02		
77.0000	.7100	.4180	.0925	79.4674	81.8793	3.0351	* .5074+00	.5603-01	.6280-02	.7032-03	.6477-04	
							* .5886-05	.5311-06	.2865-01	.1657-02	.9711-04	
77.0000	.7600	.4522	.1045	79.9675	82.2400	2.8418	* .5433+00	.6532-01	.7978-02	.9744-03	.9816-04	
							* .9767-05	.9643-06	.3041-01	.1744-02	.1013-03	
77.0000	.8100	.4870	.1160	79.7986	80.5944	.9973	* .5792+00	.7563-01	.1004-01	.1332-02	.1463-03	
							* .1587-04	.1707-05	.3221-01	.1833-02	.1057-03	
77.0000	.8600	.5224	.1275	79.4565	78.3800	-1.3549	* .6167+00	.8676-01	.1243-01	.1782-02	.2121-03	
							* .2492-04	.2906-05	.3401-01	.1922-02	.1101-03	
77.0000	.9100	.5585	.1390	78.3915	80.4652	2.6453	* .6540+00	.9872-01	.1520-01	.2341-02	.3003-03	
							* .3804-04	.4781-05	.3582-01	.2011-02	.1144-03	

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## NL002 DEMONSTRATION PROBLEM SUMMARY OF SHEAR TERM FOR TEST NO. 2

TEMP	TIME	E11 OR E12	DV/D0	STRUE	S-CALC	ERROR	XF(I), I=1, NTEPWS
77.0000	.0940	.0238	.0000	13.3055	11.9319	-10.3232	* .3525-01 .3221-04 .2943-07 .2690-10 .1766-13 * .1145-16 .7369-20 .2605-02 .1971-03 .1513-04
77.0000	.2940	.0762	.0020	38.6074	35.2627	-8.6635	* .1094+00 .8794-03 .7080-05 .5701-07 .3559-09 * .2195-11 .1343-13 .6940-02 .4511-03 .2971-04
77.0000	.4940	.1311	.0100	57.0141	53.0847	-6.8921	* .1811+00 .3706-02 .7609-04 .1563-05 .2578-07 * .4202-09 .6705-11 .1071-01 .6486-03 .3678-04
77.0000	.6940	.1886	.0250	66.0687	64.1062	-2.9705	* .2505+00 .8960-02 .4222-03 .1150-04 .3429-06 * .1002-07 .2906-09 .1415-01 .8178-03 .4785-04
77.0000	.8940	.2485	.0450	71.2136	69.4239	-2.5131	* .3190+00 .1668-01 .8782-03 .4625-04 .2038-05 * .8872-07 .3832-08 .1742-01 .9735-03 .5505-04
77.0000	1.0940	.3109	.0670	74.5885	72.3368	-3.0189	* .3882+00 .2701-01 .1898-02 .1334-03 .7941-05 * .4670-06 .2724-07 .2065-01 .1125-02 .6201-04
77.0000	1.2940	.3758	.0900	76.9483	75.6740	-1.6561	* .4585+00 .4008-01 .3546-02 .3138-03 .2375-04 * .1776-05 .1318-06 .2388-01 .1274-02 .6881-04
77.0000	1.4940	.4433	.1140	78.0795	78.3048	.2885	* .5300+00 .5580-01 .5960-02 .6366-03 .5865-04 * .5338-05 .4891-06 .2712-01 .1422-02 .7546-04
77.0000	1.6940	.5132	.1360	77.7305	74.8396	-3.7190	* .6037+00 .7531-01 .9557-02 .1213-02 .1336-03 * .1454-04 .1570-05 .1044-01 .1573-02 .8232-04
7.0000	1.8940	.5856	.1490	77.9423	76.9731	-1.2435	* .6814+00 .1028+00 .1582-01 .2436-02 .3270-03 * .4336-04 .5704-05 .3395-01 .1735-02 .8088-04

N L O O 2 D E M O N S T R A T I O N P R O B L E M  
SUMMARY OF SHEAR TERM FOR TEST NO. 3

TIME	E11 OR E12	DV/V0	STRUE	S-CALC	ERROR	XF(I), I=1,NFPMs	
77.0000	.6000	.0304	.0000	11.8450	14.2566	20.3595	.4500-01 .5919-04 .7786-07 .1028-09 .1096-12 .1157-15 .1213-18 .2598-02 .1537-03 .9201-05
77.0000	1.4000	.0724	.0008	28.6645	30.1687	5.2475	.1047+00 .6976-03 .4656-05 .3108-07 .1785-09 .1012-11 .5696-14 .5398-02 .2851-03 .1524-04
77.0000	1.9000	.0995	.0038	38.2524	38.3858	.3487	.1409+00 .1640-02 .1914-04 .2238-06 .2201-08 .2322-10 .2335-12 .6967-02 .3528-03 .1906-04
77.0000	2.4000	.1272	.0078	45.7419	45.2928	-.9819	.1767+00 .3128-02 .5555-04 .9863-06 .1564-07 .2450-09 .3807-11 .8471-02 .4157-03 .2062-04
77.0000	2.9000	.1553	.0140	50.3721	50.6319	.5157	.2118+00 .5167-02 .1266-03 .3101-05 .6876-07 .1506-08 .3272-10 .9893-02 .4710-03 .2285-08
77.0000	3.4000	.1844	.0220	53.5848	54.4690	1.6501	.2464+00 .7763-02 .2459-03 .7790-05 .2258-06 .6465-08 .1817-09 .1126-01 .5248-03 .2800-08
77.0000	3.9000	.2140	.0310	55.9026	56.9820	1.9308	.2808+00 .1095-01 .4298-03 .1687-04 .6111-06 .2187-07 .7768-09 .1260-01 .5789-03 .2687-04
77.0000	4.4000	.2442	.0410	57.5148	58.4730	1.6660	.3152+00 .1471-01 .6915-03 .3251-04 .1822-05 .6146-07 .2615-08 .1392-01 .6204-03 .2875-04
77.0000	4.9000	.2750	.0510	58.8992	59.2272	.5569	.3499+00 .1915-01 .1057-02 .5837-04 .3017-05 .1541-06 .7806-08 .1524-01 .6796-03 .3054-04
77.0000	5.4000	.3064	.0620	59.7700	59.7413	-.0480	.3845+00 .2411-01 .1527-02 .9671-04 .5771-05 .3801-06 .1989-07 .1654-01 .7287-03 .3244-04
77.0000	5.9000	.3385	.0730	60.5083	60.1190	-.6435	.4196+00 .2977-01 .2135-02 .1512-03 .1080-04 .6981-06 .4648-07 .1785-01 .7778-03 .3425-04
77.0000	6.4000	.3712	.0840	60.9824	60.3751	-.9957	.4550+00 .3611-01 .2901-02 .2331-03 .1782-04 .1346-05 .1008-06 .1916-01 .8267-03 .3605-04

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PL002 DEMONSTRATION PROGRAM  
SUMMARY OF SHEAR TEST FOR TEST NO. 3

TEMP	TIME	E11 OR E12	DV/V0	TRUE	S-CALC	ERROR	XF(1), I=1, NTFPMS		
77.0000	6.5000	.4045	.0950	61.1918	60.2098	-1.5887	.4908*00	.4316-01	.3848-02
							.2459-05	.2053-06	.2048-01
									.3031-03
									.A755-03
77.0000	7.4000	.4084	.1060	60.8359	59.0571	-2.9239	.5269*00	.5004-01	.4997-02
							.4290-05	.3957-06	.2180-01
									.4503-03
									.9243-03
									.4615-04
									.3961-04

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## NL002 DEMONSTRATION PROBLEM SUMMARY OF SHEAR TFRM FOR TEST NO. 4

TEMP	TIME	E11 OR E12	DV/VD	STRUE	S-CALC	ERROR	XC(1), I=1, NTFPMS				
77.0000	3.0000	.0382	.0000	13.5912	15.3218	12.7330	* .5625-01	.1038-03	.1915-06	.3533-09	.8901-12
							* .9734-15	.1593-17	.2622-02	.1252-03	.6042-05
77.0000	5.0000	.0645	.0010	22.9385	23.6464	3.0861	* .9330-01	.4543-03	.2215-05	.1040-07	.4930-10
							* .2224-12	.9953-15	.4041-02	.1810-03	.9153-05
77.0000	7.0000	.0913	.0030	31.4903	30.9014	-1.8700	* .1299+00	.1146-02	.1085-04	.9924-07	.8698-09
							* .7531-11	.6470-13	.5406-02	.2303-03	.9912-05
77.0000	9.0000	.1188	.0070	38.0259	36.9218	-2.9035	* .1658+00	.2375-02	.7411-04	.4900-06	.6464-08
							* .9500-10	.1305-11	.6645-02	.2743-03	.1140-04
77.0000	11.0000	.1470	.0130	41.9296	41.6498	-.6672	* .2009+00	.4056-02	.8218-04	.1665-05	.7738-07
							* .6610-09	.1209-10	.7859-02	.3147-03	.1272-04
77.0000	13.0000	.1757	.0215	44.3978	45.0839	1.5455	* .2352+00	.6193-02	.1638-03	.4335-05	.1148-06
							* .3005-04	.7800-10	.8980-02	.3517-03	.1348-04
77.0000	15.0000	.2051	.0310	45.7279	47.3950	3.6458	* .2694+00	.8839-02	.2918-03	.9631-05	.3212-06
							* .1052-07	.3459-09	.1010-01	.3877-03	.1501-04
77.0000	17.0000	.2351	.0410	46.7034	48.7149	4.3069	* .3037+00	.1293-01	.4707-03	.1913-04	.7765-06
							* .3116-07	.1240-08	.1120-01	.4231-03	.1612-04
77.0000	19.0000	.2657	.0520	47.4165	49.3208	4.0161	* .3378+00	.1549-01	.7393-03	.3837-04	.1449-05
							* .7820-07	.3679-08	.1259-01	.4574-04	.1718-04
77.0000	21.0000	.2970	.0630	47.6337	49.3848	3.6761	* .3725+00	.1904-01	.1077-02	.5820-04	.3243-05
							* .1785-06	.9748-08	.1337-01	.4917-03	.1824-04
77.0000	23.0000	.3288	.0730	47.7286	48.9623	2.5808	* .4079+00	.2408-01	.1546-02	.9572-04	.6140-05
							* .3890-06	.2445-07	.1448-01	.5268-03	.1934-04
77.0000	25.5000	.3696	.0860	47.0750	48.1110	2.2008	* .4523+00	.3211-01	.2307-02	.1657-03	.1241-04
							* .9185-06	.6743-07	.1566-01	.5696-03	.2065-04

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## NL002 DEMONSTRATION PROBLEM SUMMARY OF SHEAR TEST FOR TEST NO. 5

TIME	E11 OR E12	DV/V0	STRUE	S-CALC	ERROR	XF(1)=1 IN TERMS
77.0000	5.0000	.0253	.0000	9.2250	9.6981	5.0855
						* .3750-01 .2975-04 .2360-07 .1873-10 .1391-13
						* .1021-16 .7416-20 .1633-02 .7285-04 .3283-05
77.0000	10.0000	.0512	.0000	18.6900	17.6624	-5.4981
						* .7501-01 .2266-03 .6853-06 .2072-08 .6184-11
						* .1799-13 .5229-16 .2979-02 .1212-03 .4978-05
77.0000	14.0000	.0724	.0000	26.2150	23.3534	-10.9159
						* .1050+00 .6042-03 .3503-05 .2024-07 .1173-09
						* .6716-12 .3815-14 .4989-02 .1552-03 .6094-05
77.0000	17.5000	.0913	.0015	31.8399	27.6803	-13.0640
						* .1306+00 .1178-02 .0937-05 .0675-07 .7710-09
						* .6785-11 .5917-13 .4811-02 .1614-03 .6982-05
77.0000	22.5000	.1188	.0060	36.9354	32.8545	-11.0492
						* .1662+00 .2258-02 .3076-04 .4191-06 .5923-08
						* .8269-10 .1145-11 .5913-02 .2153-03 .7906-05
77.0000	27.5000	.1470	.0130	39.5562	36.8625	-6.8098
						* .2005+00 .3812-02 .2261-04 .1381-05 .2772-07
						* .5489-09 .1078-10 .6951-02 .2461-03 .8786-05
77.0000	32.5000	.1757	.0215	41.1772	39.7819	-3.3884
						* .2359+00 .5826-02 .1450-03 .3605-05 .0560-07
						* .2501-08 .6494-10 .7956-02 .2754-03 .9611-05
77.0000	37.5000	.2051	.0310	41.9854	41.6791	-.7416
						* .2694+00 .8315-02 .2582-03 .8018-05 .6784-06
						* .8810-08 .2820-09 .8940-02 .3037-03 .1040-04
77.0000	42.5000	.2351	.0415	42.1775	42.6811	1.1942
						* .3035+00 .1126-01 .4210-03 .1574-04 .6782-06
						* .2546-07 .1010-08 .0907-02 .3311-07 .1115-08
77.0000	47.5000	.2657	.0520	41.9872	42.9317	2.2496
						* .3379+00 .1476-01 .4503-03 .2864-04 .1375-05
						* .6518-07 .3046-08 .1088-01 .3585-03 .1191-04
77.0000	52.5000	.2970	.0620	41.4081	42.5430	2.7406
						* .3729+00 .1891-01 .0677-03 .4953-04 .2772-05
						* .1550-06 .8456-08 .1146-01 .3861-03 .1268-04

NL002 DEMONSTRATION PROBLEM

REGRESSION COEFFICIENTS ...

CO(I)

1	1.03097+00
2	-1.16290+03
3	-6.41740+03
4	-5.56108+05
5	1.65255+07
6	-1.53141+08
7	4.71936+08
8	5.15139+03
9	5.31490+04
10	-7.90460+05

THRE WFRE 75 EXPERIMENTAL TEST POINTS

THE AVERAGE DEVIATION, XRAR, WAS -.002P

THE STANDARD DEVIATION, STD, WAS .0472

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## NL002 DEMONSTRATION PROBLEM

SUMMARY OF RULK RESULTS FOR TEST NO. 1

TEMP	TIME	STRAIN	DV/VO	SR-EXACT	SR-CALC	ERROR	XF(K), K=1,NRULKS									
77.0000	.0700	.0248	.0000	5.1563	4.6866	-9.1084	*	3561-07	1268-14	4517-22	1608-20	2476-01	.2476-01	.2185-10	.2769-25	.2769-25
							*	6130-03	1518-04	7577-06	8417-00	8417-00				
							*	7774-18	3140-16	1118-23	1118-23	1118-23				
77.0000	.1100	.0388	.0006	8.0628	7.2825	-9.6776	*	6001-03	3601-06	2161-09	1296-12	3478-01	.3478-01	.0031-06	.3252-12	.3252-12
							*	1505-02	5838-04	2265-05	2328-04	2328-04				
							*	5419-09	1307-07	8382-11	8382-11	8382-11				
77.0000	.1600	.0562	.0020	11.5299	10.0365	-12.8520	*	2000-02	4000-05	8001-08	1600-10	5624-01	.5624-01	.6327-05	.6327-05	.6327-05
							*	3163-02	1779-03	1001-04	1125-03	1125-03				
							*	1265-07	2250-06	4500-09	2531-10	2531-10				
77.0000	.2100	.0736	.0043	14.4502	12.2429	-15.2752	*	4300-02	1849-04	7951-07	3419-09	7358-01	.7358-01	.2328-08	.2328-08	.2328-08
							*	5413-02	3583-03	2931-04	3164-03	3164-03				
							*	1001-06	1360-05	8450-08	4304-09	4304-09				
77.0000	.2600	.0907	.0083	16.0009	13.8574	-14.8653	*	8300-02	6889-04	5718-06	4746-08	0855-01	.0855-01	.6821-08	.6821-08	.6821-08
							*	8214-02	7449-03	6753-04	7524-03	7524-03				
							*	5661-06	6245-05	5184-07	4659-08	4659-08				
77.0000	.3100	.1075	.0129	17.3349	15.3262	-11.5877	*	1390-01	1932-03	2686-05	3733-07	1075-00	.1075-00	.1607-03	.1607-03	.1607-03
							*	1156-01	1243-02	1337-03	1405-02	1405-02				
							*	2234-05	2078-04	2888-06	3105-07	3105-07				
77.0000	.3600	.1242	.0210	17.5209	16.6491	-4.9758	*	2100-01	4410-03	9261-05	1945-06	1242-00	.1242-00	.3242-03	.3242-03	.3242-03
							*	1584-01	1518-02	2383-03	2609-02	2609-02				
							*	6808-05	5880-08	1151-05	1430-06	1430-06				
77.0000	.4100	.1409	.0265	17.6136	17.4560	-.6947	*	2950-01	8703-03	2567-04	7574-06	1805-00	.1805-00	.5858-03	.5858-03	.5858-03
							*	1984-01	2796-02	8038-03	4156-02	4156-02				
							*	1727-04	1226-03	3617-05	5005-06	5005-06				
77.0000	.4600	.1575	.0368	17.4166	17.8126	2.2735	*	3880-01	1505-02	5841-04	2266-05	1574-00	.1574-00	.0605-03	.0605-03	.0605-03
							*	2482-01	3804-02	6158-03	6112-02	6112-02				
							*	3736-04	2372-03	9202-05	1450-05	1450-05				
77.0000	.5100	.1743	.0487	17.1190	17.7002	3.3953	*	4870-01	2372-02	1155-03	5625-05	1743-00	.1743-00	.1478-02	.1478-02	.1478-02
							*	3037-01	5203-02	8225-03	8487-02	8487-02				
							*	7204-04	4133-03	2013-04	2508-05	2508-05				
77.0000	.5600	.1911	.0595	16.4532	16.7147	1.5891	*	5950-01	3540-02	2106-03	1257-04	1911-00	.1911-00	.2172-02	.2172-02	.2172-02
							*	3651-01	6976-02	1333-02	1137-01	1137-01				
							*	1293-03	6765-03	8025-04	7691-05	7691-05				
77.0000	.6100	.2021	.0702	15.5927	15.9823	2.4983	*	7020-01	4928-02	3460-03	2429-04	2081-00	.2081-00	.3000-02	.3000-02	.3000-02
							*	4331-01	9314-02	1876-02	1461-01	1461-01				
							*	2134-03	1026-02	7200-04	1468-04	1468-04				

# NONLINEAR THERMOVISCOELASTIC CHARACTERIZATION CONF

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## NL002 DEMONSTRATION PROBLEM

### SUMMARY OF BULK RESULTS FOR TEST NO. 1

TIME	STRAIN	DV/V0	SR-EXACT	SR-CALC	ERROR	XF(K),K-1,NBULKS	
77.0000	.6600	.2251	.0815	14.5323	14.8296	2.0457	* .8150-01 .6642-02 .5414-03 .4412-04 .2253+00
							* .5075-01 .1143-01 .2575-02 .1276-01 .4176-02
							* .3371-03 .1406-02 .1220-03 .2747-04
77.0000	.7100	.2427	.0925	13.5385	14.1404	4.4458	* .9250-01 .8556-02 .7915-03 .7321-04 .2427+00
							* .5891-01 .1430-01 .1470-02 .2245-01 .5449-02
							* .5041-03 .2077-02 .1921-03 .8663-04
77.0000	.7600	.2602	.1045	12.9984	12.8950	-.7951	* .1045+00 .1072-01 .1141-02 .1197-03 .2602+00
							* .6772-01 .1762-01 .4586-02 .2719-01 .7076-02
							* .7395-03 .2842-02 .2970-03 .7728-04
77.0000	.8100	.2781	.1160	12.8394	12.2328	-4.7249	* .1160+00 .1346-01 .1561-02 .1811-03 .2781+00
							* .7732-01 .2150-01 .5978-02 .3226-01 .8969-02
							* .1040-02 .3742-02 .8340-03 .1207-03
77.0000	.8600	.2961	.1275	12.8487	11.7981	-8.1770	* .1275+00 .1626-01 .2073-02 .2643-03 .2961+00
							* .8770-01 .2507-01 .7692-02 .3776-01 .1118-01
							* .1426-02 .4814-02 .6138-03 .1818-03
77.0000	.9100	.3145	.1390	11.1067	11.7722	5.6920	* .1390+00 .1932-01 .2686-02 .3733-03 .3145+00
							* .9889-01 .3110-01 .9780-02 .4371-01 .1375-01
							* .1911-02 .6076-02 .8446-03 .2656-03

N L O O 2 D E M O N S T R A T I O N P R O B L E M

SUMMARY OF RULK RFSULTS FOR TEST NO. 2

TEMP	TIME	STRAIN	DV/V0	SB-EXACT	SB-CALC	ERROR,	XF(K),K=1,NUM KS
77.0000	.0940	.0164	.0000	4.5721	3.0185	-33.9799	.2378-07 .5653-15 .1344-22 .3196-30 .1662-01
							.2762-03 .4591-05 .7630-07 .3952-09 .6568-11
							.1562-18 .9395-17 .2234-24 .3713-24
77.0000	.2940	.0514	.0020	12.3845	9.0846	-26.6457	.2000-02 .4000-05 .8001-08 .1600-10 .5162-01
							.2665-02 .1376-03 .7100-05 .1032-07 .5340-05
							.1066-07 .2065-06 .4130-09 .2132-10
77.0000	.4940	.0856	.0100	16.6468	11.7052	-29.6848	.1000-01 .1000-03 .1000-05 .1000-07 .8562-01
							.7332-02 .6278-03 .5375-04 .8563-07 .7332-08
							.7332-06 .8563-05 .8563-07 .7332-08
77.0000	.6940	.1187	.0250	16.8756	11.8986	-29.4927	.2500-01 .6250-03 .1563-04 .3006-06 .1187+00
							.1409-01 .1673-02 .1086-03 .2968-02 .3523-03
							.8808-05 .7420-04 .1855-05 .2202-06
77.0000	.8940	.1515	.0450	16.2704	10.2693	-36.8838	.4500-01 .2025-02 .0113-04 .4101-06 .1515+00
							.2296-01 .3478-02 .5271-03 .6818-02 .1033-02
							.4649-04 .3068-03 .1381-04 .2092-05
77.0000	1.0940	.1848	.0670	15.5433	9.3508	-36.8403	.6700-01 .4489-02 .3008-03 .2015-04 .1848+00
							.3414-01 .6308-02 .1166-02 .1238-01 .2288-02
							.1533-03 .8205-03 .5558-04 .1027-04
77.0000	1.2940	.2188	.0900	14.3234	10.4063	-27.3475	.9000-01 .8100-02 .7290-03 .6561-04 .2188+00
							.4785-01 .1047-01 .2290-02 .1568-01 .4137-02
							.3876-03 .1772-02 .1555-03 .3488-04
77.0000	1.4940	.2535	.1140	12.7935	12.8349	.3237	.1140+00 .1300-01 .1482-02 .1695-03 .2535+00
							.6425-01 .1629-01 .4128-02 .2800-01 .7325-02
							.8350-03 .3204-02 .8755-03 .6520-04
77.0000	1.6940	.2895	.1360	12.7902	12.7658	-.1908	.1360+00 .1850-01 .2515-02 .3431-03 .2895+00
							.8382-01 .2427-01 .7026-02 .2937-01 .1140-01
							.1550-02 .5365-02 .7283-03 .2108-03
77.0000	1.8940	.3280	.1490	11.7193	11.6045	-.9794	.1490+00 .2220-01 .3308-02 .4929-03 .3280+00
							.1076+00 .3528-01 .1157-01 .8827-01 .1603-01
							.2388-02 .7281-02 .1085-02 .3558-02

## NONLINEAR THERMOVISCOELASTIC CHARACTERIZATION CODE

## NL002 DEMONSTRATION PROGRAM

## SUMMARY OF RULK RESULTS FOR TEST NO. 3

TEMP	TIME	STRAIN	DV/VO	SB-EXACT	SR-CALC	ERPOR.	XF(K), K=1, NBUK S									
77.0000	.6000	.0212	.0000	3.4066	3.9518	16.0014	* .3045-07	.9272-15	.2823-22	.8597-30	.2122-01					
							* .4503-03	.9554-05	.2027-06	.6461-09	.1371-10					
							* .4175-18	.1967-16	.5951-24	.1271-25						
77.0000	1.4000	.0494	.0008	8.5344	9.3731	9.8270	* .8001-03	.6401-06	.5121-09	.4007-12	.8940-01					
							* .2440-02	.1205-03	.5954-05	.3952-04	.1952-05					
							* .1562-08	.3162-07	.2530-10	.1250-11						
77.0000	1.9000	.0665	.0038	11.1785	11.0742	-9.9332	* .3800-02	.1464-04	.5488-07	.2085-00	.6654-01					
							* .4428-02	.2646-03	.1961-04	.2520-03	.1682-04					
							* .6394-07	.9609-06	.1652-08	.2470-00						
77.0000	2.4000	.0836	.0078	12.8845	12.4779	-3.1561	* .7800-02	.6084-04	.4746-06	.3702-08	.8357-01					
							* .6985-02	.5838-03	.4878-04	.6519-03	.5888-05					
							* .4250-06	.5085-05	.1066-07	.5315-09						
77.0000	2.9000	.1003	.0140	13.2674	13.1560	- .8395	* .1400-01	.1960-03	.2744-05	.3842-07	.1003+00					
							* .1006-01	.1008-02	.1011-03	.1404-02	.1408-03					
							* .1971-05	.1965-04	.2752-06	.2759-07						
77.0000	3.4000	.1128	.0220	13.1536	13.2421	.6725	* .2200-01	.4880-03	.1065-04	.2343-06	.1168+00					
							* .1363-01	.1592-02	.1859-03	.2565-02	.3000-03					
							* .6599-05	.5652-04	.1243-05	.1452-04						
77.0000	3.9000	.1332	.0310	12.8918	13.0018	.8536	* .3100-01	.9610-03	.2678-04	.9235-06	.1332+00					
							* .1775-01	.2365-02	.1513-03	.4170-02	.5503-03					
							* .1706-04	.1200-03	.1065-05	.5288-04						
77.0000	4.4000	.1497	.0410	12.5333	12.2797	-2.0242	* .4100-01	.1681-02	.6892-04	.2826-05	.1497+00					
							* .2341-01	.3355-02	.5022-03	.6178-02	.9188-03					
							* .3767-04	.2516-03	.1032-04	.1545-05						
77.0000	4.9000	.1664	.0510	12.3391	11.8785	-3.7330	* .5100-01	.2601-02	.1327-03	.6765-05	.1664+00					
							* .2768-01	.4605-02	.7661-03	.8455-02	.1412-05					
							* .7199-04	.4327-03	.2207-04	.3472-05						
77.0000	5.4000	.1831	.0620	11.9512	11.0948	-7.1659	* .6200-01	.3844-02	.2383-03	.1478-04	.1831+00					
							* .3351-01	.6175-02	.1123-02	.1135-01	.2078-02					
							* .1288-03	.7017-03	.4363-04	.7987-05						
77.0000	5.9000	.2000	.0730	11.6053	10.7492	-7.3772	* .7300-01	.5329-02	.1890-03	.2840-04	.2000+00					
							* .3999-01	.7988-02	.1599-02	.1480-01	.2919-02					
							* .2131-03	.1066-02	.7780-04	.1556-04						
77.0000	6.4000	.2171	.0840	11.2165	10.7299	-4.3380	* .8400-01	.7056-02	.5927-03	.4975-04	.2171+00					
							* .4714-01	.1024-01	.2223-02	.1824-01	.3960-02					
							* .3326-03	.1512-02	.1287-03	.2768-04						

## NONLINEAR THERMOVISCOELASTIC CHARACTERIZATION CODE

NL002 DEMONSTRATION PROBLEM

SUMMARY OF BULK RESULTS FOR TEST NO. 3

TEMP	TIME	STRAIN	CV/V0	SR-EXACT	SR-CALC	ERROR,	XF(K)K=1,NRULKS
77.0000	6.9000	.2345	.0950	10.8652	10.8697	.0417	* .9500-01 .9025-02 .8574-03 .8185-04 .2345+00 * .5499-01 .1290-01 .3024-02 .2228-01 .5224-02 * .4963-03 .2116-02 .2011-03 .4715-04
77.0000	7.4000	.2521	.1060	10.5977	10.9968	3.7663	* .1060+00 .1124-01 .1151-02 .1262-03 .2521+00 * .6356-01 .1602-01 .8040-02 .2672-01 .6737-02 * .7141-03 .2833-02 .3003-03 .7570-04

# NONLINEAR THERMOVISCOELASTIC CHARACTERIZATION CODE

NL002 DEMONSTRATION PROBLEM

SUMMARY OF BULK RESULTS FOR TEST NO. 4

TEMP	TIME	STRAIN	DV/V0	SR-EXACT	SR-CALC	ERROR	XF(K)*KE(1)*RULKS
77.0000	3.0000	.0265	.0000	4.0552	5.0581	24.7329	*.3820-07 .1459-14 .5776-22 .2130-20 .2653-01 *.7039-03 .1867-04 .4953-06 .1013-09 .2689-10 *.1027-17 .3872-16 .1479-23 .3924-25
77.0000	5.0000	.0440	.0010	6.9452	8.1303	17.0634	*.1000-02 .1000-05 .1000-08 .1000-11 .8403-01 *.1938-02 .8534-04 .757-05 .4403-04 .1938-05 *.1939-08 .4403-07 .8403-10 .1939-11
77.0000	7.0000	.0614	.0030	9.4500	10.4819	10.9201	*.3000-02 .9001-05 .2700-07 .8101-10 .6137-01 *.3766-02 .2311-03 .1418-04 .1841-03 .1130-04 *.3390-07 .5523-06 .1657-08 .1017-09
77.0000	9.0000	.0784	.0070	10.9533	11.7555	7.3236	*.7000-02 .4900-04 .4030-06 .2401-08 .7837-01 *.6142-02 .4813-03 .3772-04 .5486-03 .4299-04 *.3009-06 .3840-05 .2688-07 .2107-05
77.0000	11.0000	.0951	.0130	11.2336	12.3294	9.7553	*.1300-01 .1690-03 .2197-05 .2856-07 .9507-01 *.9039-02 .8503-03 .9170-04 .1236-02 .1175-03 *.1528-05 .1607-04 .2089-06 .1986-07
77.0000	13.0000	.1114	.0215	10.9168	11.8146	8.2237	*.2150-01 .4623-03 .0939-05 .2137-06 .1114+00 *.1241-01 .1383-02 .1541-03 .2385-02 .2660-03 *.5738-05 .5150-04 .1107-05 .1234-06
77.0000	15.0000	.1277	.0310	10.2963	10.9879	6.7167	*.3100-01 .9610-03 .2679-04 .9315-06 .1277+00 *.1632-01 .2044-02 .2662-03 .3960-02 .4058-03 *.1588-04 .1228-03 .4026-05 .4861-07
77.0000	17.0000	.1442	.0410	8.7882	10.2066	4.2747	*.4100-01 .1641-02 .4502-04 .2826-06 .1442+00 *.2078-01 .2996-02 .4318-03 .5010-02 .5520-03 *.3493-04 .2423-03 .0936-05 .1432-06
77.0000	19.0000	.1606	.0520	9.3430	9.2833	-6.6382	*.5200-01 .2709-02 .1406-03 .7312-05 .4044+00 *.2578-01 .4181-03 .4850-04 .8357-02 .731-02 *.6973-04 .4333-03 .2258-05 .1621-06
77.0000	21.0000	.1773	.0630	8.8798	9.0207	1.5867	*.6300-01 .3969-02 .2501-03 .1575-04 .1772+00 *.3141-01 .5547-02 .0866-03 .1117-01 .1970-02 *.1247-03 .7034-03 .4432-04 .7854-05
77.0000	23.0000	.1943	.0730	8.6187	9.5277	10.5463	*.7300-01 .5329-02 .2890-03 .2840-04 .1943+00 *.3774-01 .7333-02 .1425-02 .1418-01 .2755-02 *.2011-03 .1035-02 .7558-04 .1468-04
77.0000	25.0000	.2158	.0860	8.0284	10.2103	27.1737	*.8600-01 .7386-02 .6361-03 .5470-04 .2158+00 *.4657-01 .1005-01 .3169-02 .1856-01 .4005-02 *.3445-03 .1586-02 .3331-03 .2231-04

# NONLINEAR THERMOVISCOELASTIC CHARACTERIZATION CODE

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## NL002 DEMONSTRATION PROBLEM

### SUMMARY OF RULK RESULTS FOR TEST NO. 5

TEMP	TIME	STRAIN	DV/V0	SD-EXACT	SR-CALC	ERROR	XF(K)*K=1.NRULKS									
77.0000	5.0000	.0177	.0000	2.9174	3.2312	10.7586	*	.2531-07	.6407-15	.1622-22	.4105-30	.1768-01				
							*	.3126-03	.5528-05	.0774-07	.8476-09	.7013-11				
							*	.2003-1A	.1113-16	.286A-24	.5070-26					
77.0000	10.0000	.0354	.0000	6.1043	6.9370	13.6406	*	.5125-07	.2627-14	.1346-21	.6899-29	.3538-01				
							*	.1252-02	.4430-04	.1567-05	.1813-08	.6416-10				
							*	.3288-17	.9294-16	.4763-23	.1685-24					
77.0000	14.0000	.0496	.0000	8.6663	9.9104	14.3584	*	.7245-07	.5240-14	.3805-21	.2755-28	.0057-01				
							*	.2457-02	.1218-03	.6039-05	.3502-07	.1780-09				
							*	.1290-16	.2602-15	.1885-22	.6346-24					
77.0000	17.5000	.0617	.0015	10.3791	11.4332	10.2090	*	.1500-02	.2250-05	.3376-08	.5064-11	.6165-03				
							*	.3806-02	.2348-03	.1484-04	.9254-04	.5700-05				
							*	.8564-08	.1388-06	.2082-09	.1285-10					
77.0000	22.5000	.0786	.0060	11.335A	12.3636	9.0673	*	.6000-02	.3600-04	.2160-06	.1296-08	.7858-01				
							*	.6175-02	.4852-03	.3813-04	.4715-03	.3705-04				
							*	.2223-06	.2829-05	.1657-07	.1334-08					
77.0000	27.5000	.0951	.0130	11.1245	12.3294	10.8310	*	.1300-01	.1600-03	.2167-05	.2856-07	.0512-01				
							*	.9039-02	.8593-03	.8170-04	.1236-02	.1176-03				
							*	.1528-05	.1607-04	.2089-06	.1036-07					
77.0000	32.5000	.1114	.0215	10.5983	11.8146	11.4784	*	.2150-01	.4623-03	.6039-05	.2137-06	.1114-03				
							*	.1241-01	.1383-02	.1541-03	.2495-02	.2669-03				
							*	.5738-05	.5150-04	.1107-05	.1234-06					
77.0000	37.5000	.1277	.0310	9.9059	10.9479	10.9223	*	.3100-01	.5610-03	.2979-04	.2255-04	.1272-00				
							*	.1632-01	.2084-02	.2682-03	.3560-02	.5058-03				
							*	.1568-04	.1228-03	.3806-05	.4841-06					
77.0000	42.5000	.1441	.0415	9.1349	9.8693	8.0390	*	.4150-01	.1722-02	.7147-04	.2566-05	.1441-00				
							*	.2075-01	.2900-02	.4307-03	.5978-02	.4612-03				
							*	.3574-04	.2481-03	.1030-04	.1883-05					
77.0000	47.5000	.1506	.0520	8.451A	9.2833	9.8393	*	.5200-01	.2704-02	.1406-03	.7312-05	.1606-00				
							*	.2579-01	.4141-02	.6650-03	.8350-02	.1381-02				
							*	.6973-04	.4347-03	.2258-04	.3626-05					
77.0000	52.5000	.1774	.0620	7.8439	9.4181	20.0686	*	.6200-01	.3884-02	.2383-03	.1878-04	.1774-00				
							*	.3148-01	.5585-02	.0908-03	.1100-03	.1952-02				
							*	.1210-03	.6820-03	.4228-04	.7502-05					

NL002 DEMONSTRATION PROBLEM

REGRESSION COEFFICIENTS ...

I	CO(I)
1	-2.57459+02
2	3.39865+04
3	5.64925+05
4	-4.14762+06
5	1.58470+02
6	1.71580+03
7	-2.02826+04
8	5.11708+04
9	-1.81813+04
10	2.16925+05
11	-1.47137+06
12	-6.37019+05
13	4.24863+06
14	6.05113+05

THERE WERE 74 EXPERIMENTAL TEST POINTS

THE AVERAGE DEVIATION, XBAR, WAS -.0128

THE STANDARD DEVIATION, STD, WAS .1134

N L 0 0 2 DEMONSTRATION PROBLEM

TEST NO. 1. FINAL SUMMARY

TEMP	TIME	STRAIN	S11	S11-CALC	ERROR	S22	S22-CALC	ERROR	PRFSUPE
77.0000	.0700	.0356	16.5600	16.5616	.1307	.0000	-.9609	.0000	.0000
77.0000	.1100	.0565	26.3671	26.1493	-.8260	.0000	-1.3628	.0000	.0000
77.0000	.1600	.0832	38.4096	37.1751	-3.2140	.0000	-1.7522	.0000	.0000
77.0000	.2100	.1105	49.2876	46.9200	-4.8038	.0000	-2.0469	.0000	.0000
77.0000	.2600	.1384	57.6174	55.0589	-4.4404	.0000	-2.1286	.0000	.0000
77.0000	.3100	.1670	64.2351	61.7938	-3.8005	.0000	-1.5761	.0000	.0000
77.0000	.3600	.1962	68.3164	67.0771	-1.8141	.0000	-.5043	.0000	.0000
77.0000	.4100	.2240	71.6129	70.7730	-1.1728	.0000	.5247	.0000	.0000
77.0000	.4600	.2564	73.8568	73.3164	-.7317	.0000	1.3323	.0000	.0000
77.0000	.5100	.2875	75.7367	75.1089	-.7101	.0000	1.7003	.0000	.0000
77.0000	.5600	.3162	77.0994	76.5084	-.7666	.0000	1.1130	.0000	.0000
77.0000	.6100	.3515	78.2113	78.3344	.1574	.0000	.6560	.0000	.0000
77.0000	.6600	.3844	79.0363	79.8876	1.0770	.0000	-.2567	.0000	.0000
77.0000	.7100	.4180	79.4674	81.2752	2.2749	.0000	-.8041	.0000	.0000
77.0000	.7600	.4522	79.9675	81.0004	1.2917	.0000	-1.2396	.0000	.0000
77.0000	.8100	.4870	79.7986	79.5899	-.2616	.0000	-1.0046	.0000	.0000
77.0000	.8600	.5224	79.4565	77.8677	-1.9997	.0000	-.5124	.0000	.0000
77.0000	.9100	.5585	78.3915	80.0938	2.1716	.0000	-.3713	.0000	.0000

## NONLINEAR THERMOVISCOELASTIC CHARACTERIZATION CODE

## NL002 DEMONSTRATION PROBLEM

## TEST NO. 2, FINAL SUMMARY

TEMP	TIME	STRAIN	S11	S11-CALC	ERROR	S22	S22-CALC	ERROR	PPFSSUPF
77.0000	.0940	.0236	13.3055	11.0051	-16.8378	.0000	-.8668	.0000	.0000
77.0000	.2940	.0762	38.6074	33.6351	-12.8792	.0000	-1.6276	.0000	.0000
77.0000	.4940	.1311	57.0141	50.1078	-12.1133	.0000	-2.9768	.0000	.0000
77.0000	.6940	.1886	66.0687	60.1104	-9.0184	.0000	-3.9958	.0000	.0000
77.0000	.8940	.2485	71.2136	64.3176	-9.6835	.0000	-5.1063	.0000	.0000
77.0000	1.0940	.3109	74.5885	67.2702	-9.8117	.0000	-5.0666	.0000	.0000
77.0000	1.2940	.3758	76.9483	72.3941	-5.9184	.0000	-3.2799	.0000	.0000
77.0000	1.4940	.4433	78.0795	78.2336	.1973	.0000	-.0712	.0000	.0000
77.0000	1.6940	.5132	77.7305	76.2806	-1.8909	.0000	1.4210	.0000	.0000
77.0000	1.8940	.5856	77.9423	77.3429	-.7690	.0000	.3654	.0000	.0000

NL002 DEMONSTRATION PROBLEM

TEST NO. 3. FINAL SUMMARY

TEMP	TIME	STRAIN	S11	S11-CALC	ERROR	S22	S22-CALC	ERROR	PRESSUPF
77.0000	.6000	.0304	11.8450	13.5959	14.781A	.0000	-.6607	.0000	.0000
77.0000	1.4000	.0724	28.6645	30.2553	5.5496	.0000	.0866	.0000	.0000
77.0000	1.9000	.0995	38.2524	38.2148	-.0984	.0000	-.1710	.0000	.0000
77.0000	2.4000	.1272	45.7419	45.1107	-1.3800	.0000	-.1821	.0000	.0000
77.0000	2.9000	.1555	50.3721	50.3906	.0368	.0000	-.2413	.0000	.0000
77.0000	3.4000	.1844	53.5448	54.1153	.9902	.0000	-.3536	.0000	.0000
77.0000	3.9000	.2140	55.9026	56.5523	1.1622	.0000	-.4296	.0000	.0000
77.0000	4.4000	.2442	57.5148	57.7402	.3919	.0000	-.7328	.0000	.0000
77.0000	4.9000	.2750	58.8992	58.6026	-.5036	.0000	-.6246	.0000	.0000
77.0000	5.4000	.3064	59.7700	58.8992	-1.4569	.0000	-.8421	.0000	.0000
77.0000	5.9000	.3385	60.5083	59.4575	-1.7366	.0000	-.7616	.0000	.0000
77.0000	6.4000	.3712	60.9824	60.1922	-1.2958	.0000	-.1830	.0000	.0000
77.0000	6.9000	.4045	61.1918	60.7003	-.7869	.0000	.4905	.0000	.0000
77.0000	7.4000	.4384	60.8359	60.3856	-.8058	.0000	1.2885	.0000	.0000

NL002 DEMONSTRATION PROBLEM

TEST NO. 4, FINAL SUMMARY

TEMP	TIME	STRAIN	S11	S11-CALC	ERROR	S22	S22-CALC	ERROR	PERSCUP
77.0000	3.0000	.0382	13.5912	15.4595	13.7460	.0000	.1377	.0000	.0000
77.0000	5.0000	.0645	22.9305	24.4776	6.7094	.0000	.8311	.0000	.0000
77.0000	7.0000	.0913	31.4903	32.2278	2.3420	.0000	1.7264	.0000	.0000
77.0000	9.0000	.1188	38.0259	38.2760	.6578	.0000	1.3542	.0000	.0000
77.0000	11.0000	.1470	41.9286	42.8856	2.2800	.0000	1.2358	.0000	.0000
77.0000	13.0000	.1757	44.3978	45.6386	2.7949	.0000	.5547	.0000	.0000
77.0000	15.0000	.2051	45.7279	47.2530	3.3353	.0000	-.1420	.0000	.0000
77.0000	17.0000	.2351	46.7034	48.1276	3.0493	.0000	-.5873	.0000	.0000
77.0000	19.0000	.2657	47.4165	48.3090	1.8923	.0000	-1.0118	.0000	.0000
77.0000	21.0000	.2970	47.6337	48.6501	2.1339	.0000	-.7348	.0000	.0000
77.0000	23.0000	.3288	47.7286	49.2544	3.1968	.0000	.0000	.0000	.0000
77.0000	25.5000	.3606	47.0750	49.7747	5.7349	.0000	1.6637	.0000	.0000

NLOO2 DEMONSTRATION PROBLEM

TEST NO. 5. FINAL SUMMARY

TEMP	TIME	STRAIN	S11	S11-CALC	ERROR	S22	S22-CALC	ERROR	PRFSSUMF
77.0000	5.0000	.0253	9.2250	9.7734	5.9451	.0000	.0793	.0000	.0000
77.0000	10.0000	.0512	18.6900	19.0089	1.7061	.0000	1.3465	.0000	.0000
77.0000	14.0000	.0724	26.2150	26.0284	-.7120	.0000	2.6750	.0000	.0000
77.0000	17.5000	.0913	31.8399	30.8192	-3.2057	.0000	3.1389	.0000	.0000
77.0000	22.5000	.1188	36.9356	35.9229	-2.7418	.0000	3.0684	.0000	.0000
77.0000	27.5000	.1470	39.5562	39.4143	-.3589	.0000	2.5517	.0000	.0000
77.0000	32.5000	.1757	41.1772	41.6959	1.2596	.0000	1.9139	.0000	.0000
77.0000	37.5000	.2051	41.9858	42.9117	2.2062	.0000	1.2376	.0000	.0000
77.0000	42.5000	.2351	42.1775	43.1637	2.3382	.0000	.4425	.0000	.0000
77.0000	47.5000	.2657	41.9872	43.2910	3.1054	.0000	.3593	.0000	.0000
77.0000	52.5000	.2970	41.4081	43.5497	5.1719	.0000	1.0067	.0000	.0000

NL002 DEMONSTRATION PROBLEM

FOR THE STRESS SIGMA-11, ...

XRAR = -.0025 AND STD = .0477

FOR THE STRESS SIGMA-22, ...

XRAR = .0000 AND STD = .0000

DATA CARDS IGNORED - FIRST IS LISTED BELOW

15 JUN 73 14:12:11 CAPE  
15 JUN 73 00:00:02.659

NO. 041-25772-1.100  
SI FOR: J1002-1.1002  
DATE: TIME: LEVEL OF OUTPUT ELEMENT: 15 JUN 73 14:12:02  
FORMAT: V: 15: VERSION: 2.6

# MAIN PROGRAM

## STORAGE USED (BLOCK, NAME, LENGTH)

0001 \*CODE 001566  
0000 \*DATA 012731  
0002 \*ALINK 000000  
0003 INPUT 007034

## EXTERNAL REFERENCES (BLOCK, NAME)

0004 JOINT  
0005 PAGE  
0006 BUFFER  
0007 RES  
0010 REF  
0011 NREF  
0012 NREF  
0013 NREF  
0014 NREF  
0015 NREF  
0016 EXP  
0017 NEXP  
0020 NSORT  
0021 NEXP  
0022 NEXP  
0023 NEXP  
0024 NEXP  
0025 NEXP

## STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0000	012071	IF	0001	000567	10L	0001	000774	100L	0001	001772	1006G	0001	002502	110L
0001	002003	110L	0001	002020	1020G	0001	002023	1031G	0001	002075	1000G	0001	002170	110L
0001	002020	110L	0001	002032	1124G	0001	002035	1031G	0001	002075	1102G	0001	002112	110L
0001	002035	1172G	0001	002035	1174G	0001	002047	12L	0001	002048	1203G	0001	002112	110L
0001	002035	1210G	0001	002045	1232G	0001	002052	1241G	0001	002055	1284G	0001	002117	110L
0001	002051	1266G	0001	002062	1274G	0001	002062	1276G	0001	002100	11F	0001	002117	110L
0001	000052	133G	0001	002200	1331G	0001	002202	1350G	0001	002222	1452G	0001	002117	110L
0001	002745	1370G	0001	002745	1372G	0001	002745	1372G	0001	002745	1372G	0001	002117	110L
0001	000049	1410G	0001	003027	1431G	0001	003105	1454G	0001	003270	1470G	0001	002117	110L
0001	002117	15F	0001	003231	1514G	0001	003253	1537G	0001	003253	1537G	0001	002117	110L
0001	000110	1556G	0001	003276	1553G	0001	003276	1553G	0001	003276	1553G	0001	002117	110L
0001	000758	1574G	0001	000132	166G	0001	000041	18L	0001	003310	1643G	0001	002117	110L
0001	000214	222G	0001	001631	207L	0001	000160	202G	0001	003742	21L	0001	002117	110L
0001	002111	30F	0001	000273	247G	0001	000160	202G	0001	003742	21L	0001	002117	110L
0001	002111	30F	0001	000355	300G	0001	000160	202G	0001	003742	21L	0001	002117	110L
0001	000427	310G	0001	000400	320G	0001	000160	202G	0001	003742	21L	0001	002117	110L
0001	000427	310G	0001	000427	310G	0001	000160	202G	0001	003742	21L	0001	002117	110L
0001	000537	412G	0001	000537	412G	0001	000160	202G	0001	003742	21L	0001	002117	110L
0001	000602	444G	0001	000602	444G	0001	000160	202G	0001	003742	21L	0001	002117	110L

[illegible]

00100	1	C	*** PROGRAM NAME = 'ALP2'
00101	2	C	NON-LINEAR THERMOVISCOELASTIC CHARACTERIZATION CORR.
00102	3	C	*****
00103	4	C	WALK = WALK MODULUS.
00104	5	C	WALK = VOLUMETRIC EXPANSION COEFFICIENT.
00105	6	C	WALK = TOTAL STRAIN SHEAR STRAIN
00106	7	C	WALK =
00107	8	C	WALK =
00108	9	C	WALK =
00109	10	C	WALK =
00110	11	C	WALK =
00111	12	C	WALK =
00112	13	C	WALK =
00113	14	C	WALK =
00114	15	C	WALK =
00115	16	C	WALK =
00116	17	C	WALK =
00117	18	C	WALK =
00118	19	C	WALK =
00119	20	C	WALK =
00120	21	C	WALK =
00121	22	C	WALK =
00122	23	C	WALK =
00123	24	C	WALK =
00124	25	C	WALK =
00125	26	C	WALK =
00126	27	C	WALK =
00127	28	C	WALK =
00128	29	C	WALK =
00129	30	C	WALK =
00130	31	C	WALK =
00131	32	C	WALK =
00132	33	C	WALK =
00133	34	C	WALK =
00134	35	C	WALK =
00135	36	C	WALK =
00136	37	C	WALK =
00137	38	C	WALK =
00138	39	C	WALK =
00139	40	C	WALK =
00140	41	C	WALK =
00141	42	C	WALK =
00142	43	C	WALK =
00143	44	C	WALK =
00144	45	C	WALK =
00145	46	C	WALK =
00146	47	C	WALK =
00147	48	C	WALK =
00148	49	C	WALK =
00149	50	C	WALK =
00150	51	C	WALK =
00151	52	C	WALK =
00152	53	C	WALK =
00153	54	C	WALK =
00154	55	C	WALK =
00155	56	C	WALK =
00156	57	C	WALK =
00157	58	C	WALK =
00158	59	C	WALK =
00159	60	C	WALK =
00160	61	C	WALK =
00161	62	C	WALK =
00162	63	C	WALK =
00163	64	C	WALK =
00164	65	C	WALK =
00165	66	C	WALK =
00166	67	C	WALK =
00167	68	C	WALK =
00168	69	C	WALK =
00169	70	C	WALK =
00170	71	C	WALK =
00171	72	C	WALK =
00172	73	C	WALK =
00173	74	C	WALK =
00174	75	C	WALK =
00175	76	C	WALK =
00176	77	C	WALK =
00177	78	C	WALK =
00178	79	C	WALK =
00179	80	C	WALK =
00180	81	C	WALK =
00181	82	C	WALK =
00182	83	C	WALK =
00183	84	C	WALK =
00184	85	C	WALK =
00185	86	C	WALK =
00186	87	C	WALK =
00187	88	C	WALK =
00188	89	C	WALK =
00189	90	C	WALK =
00190	91	C	WALK =
00191	92	C	WALK =
00192	93	C	WALK =
00193	94	C	WALK =
00194	95	C	WALK =
00195	96	C	WALK =
00196	97	C	WALK =
00197	98	C	WALK =
00198	99	C	WALK =

CONFUSION WORK1(7). WORK2(7)

**REDACTED**

C	COMMON. /INPUT/	TEST. NRP.	PRES. NRP.	KTEMP.	KODE.	WATIO.	RI.W.	ACTA.
001013	25*							
001014	26*							
001014	21*							

**ONE**



V30:AY.4/5772.1.100

00261	Ad	5	CONTINUE
00263	89*	C	D(1) = D(2)
00264	90*		NTEST = 0
00265	91*		RF*IND 11
00266	92*		RF*IND 12
00267	93*		LI*F = 0
00268	94*		CALL PAGN(LI*F, NAME)
00270	95*		WRITE(6,33)
00271	96*		DO 110 I=1,14
00273	97*		W4(I) = 0.0
00276	98*		DO 105 K=1,100
00277	99*		XF1(I,K) = 0.0
00282	100*		XF(I,K) = 0.0
00303	101*		CONTINUE
00304	102*	10*	DO 110 J=1,14
00305	103*		R(I,J) = 0.0
00307	104*		CONTINUE
00312	105*		CONTINUE
00313	106*	11*	CONTINUE
00313	107*	C	BEGIN NEXT TEST.
00313	108*	C	
00316	109*	C	CONTINUE
00316	110*	C	
00316	111*	C	ZERO ALL VARIABLES.
00316	112*	C	
00317	113*	C	DO 107 I=1,100
00317	114*		D1(I) = 0.0
00322	115*		D4(I) = 0.0
00323	116*		D2(I) = 0.0
00324	117*		D3(I) = 0.0
00325	118*		D12(I) = 0.0
00326	119*		D1(I) = 0.0
00327	120*		E1(I) = 0.0
00330	121*		E2(I) = 0.0
00331	122*		E3(I) = 0.0
00332	123*		E12(I) = 0.0
00333	124*		F(I) = 0.0
00334	125*		G(I) = 0.0
00335	126*		IND1(I) = 0.000
00336	127*		IND2(I) = 0.000
00337	128*		IND3(I) = 0.000
00340	129*		NGROWF(I) = 0.000
00341	130*		RATF(I) = 0.0
00342	131*		STOPSA(I) = 0.0
00343	132*		STAGE(I) = 0.0
00344	133*		T(I) = 0.0
00345	134*		TEAP(I) = 0.0
00346	135*		TK(I) = 0.0
00347	136*		DO 107 J=1,6
00352	137*		NORV(K,I) = 0.000
00353	138*	107	CONTINUE
00353	139*	C	
00353	140*	C	INPUT RAW DATA FOR THIS TEST.
00353	141*	C	
00356	142*		CALL BUFFER (NU, IFLAG)
00356	143*	C	
00356	144*	C	
00357	145*		NTEST = NTEST + 1
00360	146*		NI = N
00361	147*		LINE = LINE + 1

VMS:AY24:077201.100

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00362 1440 IF(1.0E-50) GO TO 34
00364 1440 CALL PAGNLT(IPR, NAME)
00365 1500 WRITE(6,23)
00367 1510 LT=0
00370 1520 34 CONTINUE
00371 1530 WRITE(6,35) NTEST,ITEST,NODP,NORM,TEMP,DRES,TEMP(I)
00371 1540 C
00371 1550 C COMPUTE THE REDUCED TIME, TR.
00371 1560 C
00402 1570 DO A TEMP,NODP
00405 1580 IF(1.0E-11) GO TO 9
00407 1590 *DIAGNOSTIC* THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
00411 1600 IF(TEMP(I)-EG,TEMP(I-1)) GO TO 10
00414 1610 DO 11 J=1,NAT
00416 1620 IF(TEMP(I)-LT,TSFT(J)) GO TO 12
00420 1630 11 CONTINUE
00421 1640 12 AVAL = ( EXPLOG(ATCU-1)) + D(I)*(TEMP(I) - TSFT(J-1)) )
00422 1650 10 TR(I) = TR(I-1) + D(I)/AVAL
00422 1660 8 CONTINUE
00422 1670 C
00422 1680 C IF TEMP IS CONSTANT READ 10TH THRU 40TH NODPS, OTHERWISE
00422 1690 C COMPUTE THEM BASED ON THE REDUCED TIME, TR.
00422 1700 C
00424 1710 IF(TEMP,F3.2) GO TO 18
00424 1720 C
00424 1730 C
00424 1740 C
00424 1750 C
00426 1760 DO 60 M=1.6
00431 1770 XP = 1.0/(TEMP)
00432 1780 DO 60 I=1,NODP
00435 1790 NORM(I,1) = NORM(I,1) + (1./AVGAT(I)*XP)
00436 1800 60 CONTINUE
00441 1810 GO TO 19
00442 1820 18 CONTINUE
00442 1830 C
00443 1840 DO 20 M=1.6
00445 1850 XP = 1.0*(1.0/M)
00447 1860 XC = 1.0*(1.0/M)
00450 1870 DO 20 I=1,NODP
00453 1880 DTR = TR(I) - TR(I-1)
00454 1890 A1 = DARS(INV2(I))
00455 1900 A2 = DARS(INV2(I-1))
00456 1910 *DIAGNOSTIC* THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
00456 1920 IF(1.0E-42) GO TO 21
00460 1930 NORM(I,1) = NORM(I,1) + (A1*XP-A2*XP)/(XP*(A1-A2)/DTR )
00461 1940 GO TO 20
00462 1950 21 CONTINUE
00463 1960 NORM(I,1) = N/3*(M,I-1) + (A1*XP)*DTR
00464 1970 20 CONTINUE
00464 1980 C
00467 1990 DO 22 M=1.6
00472 2000 XP = 1.0/M
00473 2010 XC = 1./XP
00474 2020 DO 22 I=1,NODP
00477 2030 NORM(I,1) = NORM(I,1)*XP
00500 2040 22 CONTINUE
00500 2050 C
00503 2060 19 CONTINUE

```

VRG:AY:425772J:100

```

00503 206* C
00503 207* C
00503 208* C
00503 209* C
00503 210* C
00503 211* C
00504 212* F(I) = 0.0
00505 213* DO 65 J=1,NP
00510 214* XF1(I,J) = F1(I)
00511 215* XF2(I,J) = E2(I)
00512 216* XF1(I,J) = F1(I) - E2(I)
00513 217* G(I) = (1.0 - DABS(I*W2(I))/NORM(F(I)))**2
00514 218* F(I) = DEXP(A*INV3(I)/(NSORT(DABS(TRY2(I))))))
00515 219* IF(IFF(I).EQ.0) GO TO 55
00517 220* XF1(I,J) = XF1(I,J)*F(I)
00520 221* XF2(I,J) = XF2(I,J)*F(I)
00521 222* XF1(I,J) = XF1(I,J)*F(I)
00522 223* CONTINUE
00522 224* 65
00524 225* C
00524 226* C
00524 227* C
00524 228* C
00525 229* NGMS = 0
00530 230* DO 50 K=1,6
00531 231* W = TR(K)
00531 232* IF(W.EQ.0) GO TO 50
00533 233* NGMS = NGMS + 1
00534 234* DO 55 J=1,NDP
00535 235* DT = ( DABS(I*W2(J))/NORM(M(J)))**2
00540 236* XF1(K,J) = XF1(I,J)*DT
00542 237* XF2(K,J) = XF2(I,J)*DT
00543 238* XF1(K,J) = XF1(I,J)*DT
00544 239* IF(IFF(K).EQ.0) GO TO 55
00546 240* XF1(K,J) = XF1(K,J)*F(K)
00547 241* XF2(K,J) = XF2(K,J)*F(K)
00550 242* XF1(K,J) = XF1(K,J)*F(K)
00551 243* 55
00551 244* C
00553 245* 50
00553 246* C
00553 247* C
00553 248* C
00553 249* C
00555 250* DO 70 K=1, NP
00560 251* NP2 = NP + 7
00561 252* DO 70 J=1,NDP
00564 253* AT = P(M) + 1.
00565 254* INT1 = 0.0
00566 255* INT2 = 0.0
00567 256* INT12 = 0.0
00570 257* DO 71 K=1,J
00573 258* IF(KONF.EQ.3) GO TO 7A
00575 259* INT1 = INT1 - (DRI(K)/(R(M)*3))**2
00576 260* INT2 = INT2 - (DRI(K)/(R(M)*3))**2
00577 261* INT12 = INT12 - ((1. + R(M)*(TR(J)-TR(K)))**3
00577 262* 1 - ((1. + R(M)*(TR(J)-TR(K)))**3
00577 263* GO TO 71
00600 264* 7A
00601 265* CONTINUE
INT12= INT12- (DP12(K)/(P(M)*A3))**2
INT1= INT1- (DP1(K)/(P(M)*A3))**2
INT12= INT12- (DP1(K)/(P(M)*A3))**2

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00601 266* 71 CONTINUE - (1. + RMI*(TR(J)-TR(K-1)))**0.3 )
00602 267* XF1(NM,J) = INT1
00604 268* XF2(NM,J) = INT2
00605 269* IF (IFEMPT).NE.0) XF1(NM,J) = XF1(NM,J)*F(J)
00606 270* IF (IFEMPT).NE.0) XF2(NM,J) = XF2(NM,J)*F(J)
00610 271* IF (IFGIV).NE.0) XF1(NM,J) = XF1(NM,J)*G(J)
00612 272* IF (IFGIV).NE.0) XF2(NM,J) = XF2(NM,J)*G(J)
00614 273* XF1(NM,J) = XF1(NM,J) - XF2(NM,J)
00616 274* XF2(NM,J) = XF2(NM,J)
00617 275* CONTINUE
00617 276* C
00617 277* C FORM PRIMARY MATRIX P, AND SOLUTION VECTOR BR.
00617 278* C
00622 279* NTERMS = NORMS + NPL + 1
00622 280* C
00623 281* DO 300 K=1,NTERMS
00626 282* DO 300 J=1,NTERMS
00631 283* DO 310 I=1,NMP
00634 284* IF (A%(STRUF(I),I),LT.0) GO TO 310
00636 285* RIK(J) = RIK(J) + XF(K,I)*VF(I,I)/STRUF(I)**2
00637 286* IF (J.GT.1) GO TO 310
00641 287* RIK(I) = HIK(I) + XF(K,I)/STRUF(I)
00642 288* CONTINUE
00644 289* 310 CONTINUE
00644 290* C
00644 291* C SAVE DATA ON SCRATCH OPUS 11 AND 12.
00644 292* C
00647 293* WRITE(11) NMP, KOFF, POF5
00654 294* WRITE(11) (ZL(I), Z11(I), E10(I),FOCT(I), INV1(I), LNV2(I)
00654 295* , TAV3(I), STRUF(I), T(I), TEMP(I), I=1,NMP)
00673 296* WRITE(11) ((XF1(K,I), XF2(K,I),KE1(I),I=1,NMP)
00673 297* , K=1,NMP)
00673 298* C
00673 299* C
00673 300* C
00673 301* C GO READ NEXT YFST.
00673 302* C
00673 303* C ALL DONE ?
00673 304* C
00673 305* C
00673 306* C IF (IFLAG.EQ.2) GO TO 200
00673 307* C
00673 308* C GO TO 100
00673 309* C
00673 310* C
00673 311* C CONTINUE
00673 312* C REWIND 12
00673 313* C
00673 314* C REGRESSION ANALYSIS FOR SHEAR TERM.
00673 315* C
00673 316* C CALL HFRINTERVS, PR, CO, R )
00673 317* C
00673 318* C CALCULATE SHEAR TERM AND RELATIVE AND GLOBAL ERROR.
00673 319* C
00673 320* C
00673 321* C
00673 322* C
00673 323* C
00673 324* C
00673 325* C

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00746 320* READ(11) NDP, KMPF, PRES
00753 321* READ(11) DIL(1), F11(1), F12(1), F0CT(1), INV1(1), INV2(1)
00753 322* 1, TVN3(1), STAU(1), T(1), TEMP(1), I=1,NDP)
00772 323* READ(11) (( XF1(K,1), XF2(K,1), K=1,14), I=1,NDP)
01004 330* READ(12) (STRESS(1), I=1,NDP)
01012 331* READ(12) (( XF(K,1), K=1,14), I=1,NDP)
01023 332* LTOT = NTOT + NDP
01024 333* DO 400 I=1,NDP
01027 334* SCAL = 0.0
01030 335* DO 410 J=1,NTERMS
01033 336* SCAL = SCAL + C0(I)*XF(J,1)
01034 337* CONTINUE
01036 338* 610
01037 339* DEF = 100*(SCAL - STAU(1))/STAU(1)
01041 340* IF (ABS(STAU(1)).LT.0.01) GO TO 405
01042 341* SUM = SUM + DEF/100.
01043 342* RESID = RESID + DEF**2/10.**6
01044 343* CONTINUE
01045 344* STAN = F11(1)
01047 345* IF (CODE.EQ.3) STAN = F12(1)
01047 346* WRITE(6,660) TEMP(1), T(1), STAN, DIL(1), STAU(1), SCAL, DEF,
01047 347* 1, LIPF = LIPF + 4,
01047 348* LIPF = LIPF + 4
01065 349* IF (LIPF.LT.40) GO TO 400
01067 350* CALL PAGCL(IPG, NAME)
01073 351* WRITE(6,650) 1
01074 352* LIPF = 0
01074 353* 600 CONTINUE
01074 354* C
01074 355* C
01074 356* C
01077 357* XERR = SUM/NTOT
01077 358* STD = (NTERMS-SUM**2/(NTERMS-1))**.5
01100 359* CALL PAGCL(IPG, NAME)
01100 360* WRITE(6,701) C0(1), I=1,NTERMS
01102 361* WRITE(6,71) NTOT, XERR, STD
01111 362* C
01111 363* C
01111 364* C
01111 365* C
01116 366* KATLKS = 14
01116 367* C
01116 368* C
01116 369* C
01117 370* DO 505 K=1,14
01117 371* R0(K) = 0.0
01122 372* DO 506 I=1,100
01123 373* 506 XF(K,I) = 0.0
01126 374* C
01126 375* C
01130 376* DO 505 J=1,14
01130 377* R0(J) = 0.0
01133 378* CONTINUE
01134 379* 505
01137 380* REMIND 11
01140 381* REMIND 12
01141 382* DO 500 I=1,NTFST
01144 383* READ(11) NDP, KMPF, PRES
01151 384* READ(11) DIL(1), F11(1), F12(1), F0CT(1), INV1(1), INV2(1)
01151 385* 1, TVN3(1), STAU(1), T(1), TEMP(1), I=1,NDP)
01178 386* READ(11) (( XF1(K,1), XF2(K,1), K=1,14), I=1,NDP)
01202 387* C
01202 388* DO 501 I=1,100
01205 389* 501 STRESS(I) = 0.0

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01205 3000 C
01206 3070 C
01207 3080 DO 510 I=1,NNDP
01212 3090 STRESS(I) = STRE(I)/2. - PRES
01212 3900 C
01212 3910 X= NNDP RECOMPS SOLUTION MATRIX FOR THE NNDP'S TERMS.
01212 3920 C
01213 3930 X(1,1) = NIL(I)
01214 3940 X(2,1) = NIL(I)**2
01215 3950 X(3,1) = NIL(I)**3
01216 3960 X(4,1) = NIL(I)**4
01217 3970 X(5,1) = FOC(I)
01220 3980 X(6,1) = FOC(I)**2
01221 3990 X(7,1) = FOC(I)**3
01222 4000 X(8,1) = FOC(I)**4
01223 4010 X(9,1) = FOC(I)*NIL(I)
01224 4020 X(10,1) = FOC(I)**2*NIL(I)
01225 4030 X(11,1) = FOC(I)**2*NIL(I)**2
01226 4040 X(12,1) = FOC(I)**2*NIL(I)**3
01227 4050 X(13,1) = FOC(I)**2*NIL(I)**4
01228 4060 X(14,1) = FOC(I)**2*NIL(I)**5
01229 4070 DO 510 K=1,NTERMS
01230 4080 STRESS(I) = STRESS(I) - CO(K)*X(14,1)/2 - CO(K)*X(2(K,1))/2
01231 4090 CONTINUE
01232 4100 C
01233 4110 FORM PRIMARY MATRIX P, AND SOLUTION VECTOR QR.
01234 4120 C
01235 4130 C
01236 4140 DO 520 K=1,NNDP'S
01237 4150 C
01238 4160 DO 530 I=1,NNDP
01239 4170 IF (ABS(STRESS(I))*LT,P,0) GO TO 510
01240 4180 P(I,K) = P(I,K) + X(6,1)*X(14,1)/STRESS(I)**2
01241 4190 IF (J,GT,1) GO TO 530
01242 4200 Q(K) = Q(K) + X(6,1)/STRESS(I)
01243 4210 CONTINUE
01244 4220 C
01245 4230 C
01246 4240 WRITE(12) (STRESS(I), I=1,NNDP)
01247 4250 WRITE(12) (( X(6,1)*X(14,1),I=1,NNDP)
01248 4260 C
01249 4270 DO 500 CONTINUE
01250 4280 C
01251 4290 REWIND 11
01252 4300 REWIND 12
01253 4310 C
01254 4320 CALL REGR( NNDP'S, QR, RO, R )
01255 4330 C
01256 4340 FINAL STRESS AND ERROR CALCULATIONS.
01257 4350 C
01258 4360 SQR = 0.0
01259 4370 RECID = 0.0
01260 4380 DO 550 I=1,NTFST
01261 4390 LTIE = 0
01262 4400 CALL PARGL( IP6, NAME )
01263 4410 READ(11) NPP, KODE, PRES
01264 4420 READ(11) QIL(I), F1(I), E1(I), FOC(I), INVI(I), INV2(I)
01265 4430 READ(11) STRE(I), Y(I), TEMP(I), I=1,NNDP)
01266 4440 I = INV3(I), STRE(I), Y(I), TEMP(I), I=1,NNDP)
01267 4450 READ(11) (( X(6,1), X(2(K,1)),I=1,NNDP)
01268 4460
01269 4470
01270 4480
01271 4490
01272 4500
01273 4510
01274 4520
01275 4530
01276 4540
01277 4550
01278 4560
01279 4570
01280 4580
01281 4590
01282 4600
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01287 4650
01288 4660
01289 4670
01290 4680
01291 4690
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01298 4760
01299 4770
01300 4780
01301 4790
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01309 4870
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01316 4940
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01318 4960
01319 4970
01320 4980
01321 4990
01322 5000
01323 5010
01324 5020
01325 5030
01326 5040
01327 5050
01328 5060
01329 5070
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01331 5090
01332 5100
01333 5110
01334 5120
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01980 11580
01981 11590
01982 11600
01983 11610
01984 11620
01985 11630
01986 11640
01987 11650
01988 11660
01989 11670
01990 11680
01991 11690
01992 11700
01993 11710
01994 11720
01995 11730
01996 11740
01997 11750
01998 11760
01999 11770
02000 11780

```

WFOUAY,4,4772,1,100

```

01360 4400  IFAC(12) (STRESS(I), I=1,NP)
01366 4470  IFAC(12) ((XF(K),K=1,14),I=1,NP)
01377 4480  DO 550 I=1,NP
01402 4570  PCAL = 0.0
01403 4580  DO 550 J=1,NPULKS
01406 4590  PCAL = PCAL + PO(J)*XF(J,I)
01407 4520  CONTINUE
01411 4530  DEF = 100*(PCAL - STRESS(I))/STRESS(I)
01412 4540  IF(LABS(STRESS(I)).LT.P.0) GO TO 565
01414 4550  SUM = SUM + DEF/100.
01415 4560  RFSID = RFSID + DEF**2/10.**4
01416 4570  CONTINUE
01417 4580  565
01420 4590  STAN=EOCT(I)
01421 4600  IF(IEP(I), I(I), STAN, OIL(I), STRESS(I), PCAL, DEF,
01422 4610  )
01423 4620  WRITE(6,660) (XF(J,I),J=1,NPULKS)
01424 4630  LTRF = LTRF + 4
01425 4640  IF(LINF.LT.48) GO TO 550
01426 4650  CALL PACAL(IPG, NAME)
01427 4660  WRITE(6,655) I
01428 4670  LTRF = 0
01429 4680  CONTINUE
01430 4690  550 CONTINUE
01431 4700  ENGR SUMMARY AND COEFFICIENTS FOR RULK TERM.
01432 4710  C
01433 4720  C
01434 4730  C
01435 4740  C
01436 4750  C
01437 4760  C
01438 4770  C
01439 4780  C
01440 4790  C
01441 4800  C
01442 4810  C
01443 4820  C
01444 4830  C
01445 4840  C
01446 4850  C
01447 4860  C
01448 4870  C
01449 4880  C
01450 4890  C
01451 4900  C
01452 4910  C
01453 4920  C
01454 4930  C
01455 4940  C
01456 4950  C
01457 4960  C
01458 4970  C
01459 4980  C
01460 4990  C
01461 5000  C
01462 5010  C
01463 5020  C
01464 5030  C
01465 5040  C
01466 5050  C

```

V060454-5772-1.100

```

01607 506* DEVI = 100*(SICAL - S1)/S1
01610 507* DEV2 = 100*(S2CAL - S2)/S2
01611 508* IF (ABS(S1).LT.A) GO TO 506
01613 509* S1 = S1*1 + DEVI/170.
01614 510* RES101 = RES101 + DEVI**2/10.004
01615 511* 584
01617 512* IF (ABS(S2).LT.A) GO TO 507
01620 513* SUM2 = SUM2 + DEV2/100.
01621 514* RES102 = RES102 + DEV2**2/10.004
01622 515* CONTINUE
01623 516* STOP = E11(I)
01624 517* C
01625 518* 1
01626 519* WRITE(6,508) TEMP(1), Y(1), STRN, S1, SICAL, DEVI, S2, S2CAL.
01627 520* 1
01628 521* LEV = LEV + 2
01629 522* IF (LI.F.LT.WR) GO TO 575
01630 523* CALL PAGALL(109, NAME)
01631 524* WRITE(6,675) L
01632 525* LIF = 0
01633 526* CONTINUE
01634 527* 575
01635 528* C
01636 529* XGRP = SUM1/NIOT
01637 530* S10 = (NIOT*RES101-SUM2**2)/(NIOT*(NIOT-1))**0.5
01638 531* CALL PAGALL(105, NAME)
01639 532* WRITE(6,720) XGRP, STD
01640 533* XGRP = SUM2/NIOT
01641 534* S10 = (NIOT*RES102-SUM2**2)/(NIOT*(NIOT-1))**0.5
01642 535* WRITE(6,725) XGRP, STD
01643 536* C
01644 537* C
01645 538* C
01646 539* C
01647 540* C
01648 541* C
01649 542* C
01650 543* C
01651 544* C
01652 545* C
01653 546* C
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01655 548* C
01656 549* C
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01658 551* C
01659 552* C
01660 553* C
01661 554* C
01662 555* C
01663 556* C
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01675 568* C
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01999 892* C
02000 893* C

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Q43

EXP : 0420

U.S. AIR FORCE 5772.1.100

F11	0101	1104	0327	0510	0512	0650	0753	010044	01151	01327	01512	01622
F12	0101	0104	0327	0654	0753	010045	01151	01327	01512			
F22	0101	0104	0327	0511	0512							
F33	0101	0104	0331	0514	0517	0520	0621	0546	0547	0550	0606	0610
F	0101	0333	0504	0514	0517							
6	0117	0534	0513	0612	0614							
I	0117	0131	0145	0153	0164	0200	0211	0220	0245	0255	0260	0273
	0312	0317	0322	0323	0324	0325	0326	0327	0330	0331	0332	0334
	0341	0342	0343	0344	0345	0346	0347	0348	0349	0350	0351	0352
	0353	0354	0355	0356	0357	0358	0359	0360	0361	0362	0363	0364
	0365	0366	0367	0368	0369	0370	0371	0372	0373	0374	0375	0376
	0377	0378	0379	0380	0381	0382	0383	0384	0385	0386	0387	0388
	0389	0390	0391	0392	0393	0394	0395	0396	0397	0398	0399	0400
	0401	0402	0403	0404	0405	0406	0407	0408	0409	0410	0411	0412
	0413	0414	0415	0416	0417	0418	0419	0420	0421	0422	0423	0424
	0425	0426	0427	0428	0429	0430	0431	0432	0433	0434	0435	0436
	0437	0438	0439	0440	0441	0442	0443	0444	0445	0446	0447	0448
	0449	0450	0451	0452	0453	0454	0455	0456	0457	0458	0459	0460
	0461	0462	0463	0464	0465	0466	0467	0468	0469	0470	0471	0472
	0473	0474	0475	0476	0477	0478	0479	0480	0481	0482	0483	0484
	0485	0486	0487	0488	0489	0490	0491	0492	0493	0494	0495	0496
	0497	0498	0499	0500	0501	0502	0503	0504	0505	0506	0507	0508
	0509	0510	0511	0512	0513	0514	0515	0516	0517	0518	0519	0520
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	0545	0546	0547	0548	0549	0550	0551	0552	0553	0554	0555	0556
	0557	0558	0559	0560	0561	0562	0563	0564	0565	0566	0567	0568
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	0605	0606	0607	0608	0609	0610	0611	0612	0613	0614	0615	0616
	0617	0618	0619	0620	0621	0622	0623	0624	0625	0626	0627	0628
	0629	0630	0631	0632	0633	0634	0635	0636	0637	0638	0639	0640
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	0653	0654	0655	0656	0657	0658	0659	0660	0661	0662	0663	0664
	0665	0666	0667	0668	0669	0670	0671	0672	0673			



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INTEGER, ONSTARTS----
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[illegible]

VICINAV.425772.1.100

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01012	01330	01047	01100	01102	01117	01123	01141	01151	01170	01202	01413	01231	01240	01243
01254	01264	01272	01312	01327	01346	01360	01366	01403	01420	01451	01475	01512	01531	01542
01551	01567	01576	01653	01662	01674	01682	01692	01724	01726	01726	01724	01752	01761	01763
2:	01553	0453	0424	0656	0724	01662	01662	01662	01662	01662	01662	01662	01662	01662
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REAL CONSTANTS-----

0.000000000000	0276	0302	0303	0304	0312	0322	0323	0324	0325	0326	0327	0330	0331	0332	0333	0334
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0.000000000000	01205	01310	01311	01402	01471	01472	01473	01474	01475	01476	01477	01478	01479	01480	01481	01482
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0.750000000000	01114	0435	0445	0473	0513	0524	0575	0576	0601	0601	0601	0601	0601	0601	0601	0601
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0.100000000000	0445	0447	0472	01052	01015	01614	01620	01620	01620	01620	01620	01620	01620	01620	01620	01620
0.100000000000	01041	01414	01613	01617	01617	01617	01617	01617	01617	01617	01617	01617	01617	01617	01617	01617

FOUR PRECISION CONSTANTS-----

0.000000000000	0335	0336	0337	0340	0352
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END OF VICINAV 110A FORTMAN V COMPILATION. 2 \*DIAGNOSTIC MESSAGE(S)

PL002 CORE RELOCATABLE

15 JUN 73 13:44:01 0 00213314 14 583 (DELETED)  
15 JUN 73 13:44:01 0 00233256 18 235 (DELETED)  
15 JUN 73 13:44:01 1 00241610 36 1

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## APPENDIX E

### CHARACTERIZATION CODE NL003

#### 1.0 INTRODUCTION

The computer code NL003 is identical in input and operation as NL002 and performs the identical distortional characterization. NL003 differs from NL002 in the bulk characterization. In this code the dilatation is expressed in terms of the mean pressure and the octahedral shear strain as discussed in the text of this report.

Since the code operation is identical only a sample problem and the listing is provided in this appendix.

NL003 DEMONSTRATION PROBLEM

A = -.100+01  
Z = .100+01

POWER LAW TERMS, (1 + R\*T)\*\*P

I	H(I)	P(I)	IFG(I)
1	1.000+10	-1.330-01	0
2	1.000+10	-2.660-01	0
3	1.000+10	-4.000-01	0
4	0.000	0.000	0
5	0.000	0.000	0
6	0.000	0.000	0
7	0.000	0.000	0

I IFF(I)

1	1
2	1
3	1
4	1
5	1
6	1
7	1
8	1
9	1
10	1
11	1
12	1
13	1
14	1

I	FORM	XN(I)
1	30	2.000+00
2	30	4.000+00
3	30	6.000+00
4	40	8.000+00
5	50	1.000+01
6	60	1.200+01

NL003 DEMONSTRATION PROGRAM

TEMPERATURE 10 VALUES OF SHIFT FUNCTION VS. TEMPERATURE ...

I	AT(I)	TSFT(I)
1	1.010+10	-9.000+01
2	1.000+08	-6.500+01
3	1.500+06	-4.000+01
4	6.000+04	-2.000+01
5	3.000+03	0.000
6	2.800+01	4.000+01
7	1.000+00	7.700+01
8	2.500-01	1.000+02
9	3.000-02	1.400+01
10	1.000-02	1.600+02

TEST NO.	TEST ID	NL003 NDP	DEMONSTRATION CODE	TEMP KTEMP	PRFSURE	TEMP
1	U00300	20	1	1	.00	77.0
2	U10300	16	1	1	50.00	77.0
3	U10305	25	1	1	100.00	77.0
4	U10322	14	1	1	500.00	77.0
5	U10326	16	1	1	1000.00	77.0

NONLINEAR THERMOVISCOELASTIC CHARACTERIZATION CODE PAGE 4

N L O O 3 D E M O N S T R A T I O N P R O G R A M  
SUMMARY OF SHEAR TEST FOR TEST NO. 1

TEMP	TIME	E11 OR E12	DV/V0	STRUE	S-CALC	ERROR	XF(1), I=1, NTRFWS	
.7700+02	.7000+01	.3561-01	.3561-07	.1656+02	.1436+02	.1084+02	.5216-01 .1044-03 .2234-06 .4625-09 .6710-12	.2535-04
							.9674-15 .1340-17 .4034-02 .3175-03	
.7700+02	.1100+00	.5551-01	.6001-03	.2637+02	.2595+02	-.1584+01	.8223-01 .4022-03 .1969-05 .9617-08 .3426-10	.1109-04
							.1203-12 .4102-15 .5947-02 .4405-03	
.7700+02	.1600+00	.8320-01	.2900-02	.3941+02	.3924+02	.2154+01	.1191+00 .1182-02 .1174-04 .1167-06 .8614-09	.4121-04
							.6311-11 .4577-13 .4195-02 .5773-03	
.7700+02	.2100+00	.1105+00	.4300-02	.4929+02	.5543+02	.1246+02	.1557+00 .2556-02 .4204-04 .6574-06 .8648-08	.4825-04
							.1067-00 .1305-11 .1033-01 .7014-03	
.7700+02	.2600+00	.1384+00	.8300-02	.5762+02	.7043+02	.2224+02	.1916+00 .4603-02 .1110-03 .2676-05 .4969-07	.5444-04
							.5113-09 .1658-10 .1235-01 .4145-03	
.7700+02	.3100+00	.1670+00	.1390-01	.6424+02	.8110+02	.2626+02	.2270+00 .7349-02 .2404-03 .7842-05 .1004-06	.6000-04
							.5007-04 .1244-09 .1424-01 .9194-03	
.7700+02	.3600+00	.1962+00	.1100-01	.6432+02	.8624+02	.2624+02	.2620+00 .1046-01 .4532-03 .1801-04 .6211-06	.6515-04
							.2015-07 .6487-08 .1615-01 .1015-02	
.7700+02	.4100+00	.2260+00	.2950-01	.7161+02	.8671+02	.2104+02	.2967+00 .1507-01 .7709-03 .1403-04 .1602-05	.6005-04
							.6432-07 .2562-08 .1767-01 .1115-02	
.7700+02	.4600+00	.2564+00	.3840-01	.7386+02	.8456+02	.1449+02	.3314+00 .2002-01 .1220-02 .7432-04 .3423-05	.7471-04
							.1745-06 .8117-08 .1977-01 .1204-02	
.7700+02	.5100+00	.2875+00	.4870-01	.7574+02	.8197+02	.8231+01	.3642+00 .2573-01 .1825-02 .1205-03 .7196-05	.7032-04
							.4174-06 .2337-07 .2156-01 .1299-02	
.7700+02	.5600+00	.3192+00	.5950-01	.7710+02	.8061+02	.4554+01	.4010+00 .3209-01 .2596-02 .2100-03 .1377-04	.4376-04
							.8913-06 .5725-07 .2332-01 .1389-02	
.7700+02	.6100+00	.3515+00	.7020-01	.7921+02	.8182+02	.4614+01	.4362+00 .3032-01 .1547-02 .3273-03 .2431-04	.4427-04
							.1784-05 .1204-06 .2510-01 .1479-02	

# NONLINEAR THERMOVISCOELASTIC CHARACTERIZATION CODE PAGE 5

N L 0 0 3 D E F O N S T R A T I O N P R O B L E M  
SUMMARY OF SHEAR TERM FOR TEST NO. 1

TEMP	TIME	E11 OR E12	NU/V0	STRUE	S-CALC	ERROR	XF(I), I=1,NTEPVS	
.7700+02	.6500+00	.3844+00	.8150-01	.7904+02	.8484+02	.7345+01	.4715+00 .4721-01 .8790-02 .4859-03	.4033-04
							.3306-05 .2689-06 .2686-01 .1568-02	.0268-04
.7700+02	.7100+00	.4180+00	.9250-01	.7947+02	.8961+02	.1276+02	.5074+00 .5603-01 .6280-02 .7038-03	.6477-04
							.5888-05 .5311-06 .2865-01 .1657-02	.0711-04
.7700+02	.7500+00	.4522+00	.1045+00	.7997+02	.9195+02	.1498+02	.5433+00 .6532-01 .7978-02 .9784-03	.0816-04
							.9767-05 .9443-06 .1041-01 .1744-02	.1013-03
.7700+02	.8100+00	.4870+00	.1160+00	.7980+02	.9234+02	.1572+02	.5798+00 .7563-01 .1004-01 .1332-02	.1863-03
							.1587-04 .1707-05 .1221-01 .1833-02	.1057-03
.7700+02	.8500+00	.5224+00	.1275+00	.7946+02	.8702+02	.9514+01	.6167+00 .8676-01 .1243-01 .1782-02	.2121-02
							.2492-04 .2906-05 .1401-01 .1922-02	.1101-03
.7700+02	.9100+00	.5585+00	.1390+00	.7839+02	.7330+02	-.6485+01	.6540+00 .9872-01 .1520-01 .2241-02	.1003-03
							.3804-04 .4741-05 .1582-01 .2011-02	.1144-03

N1003 DEMONSTRATION PEOPLE  
 SUMMARY OF SHEAR TERM FOR TEST NO. 2

TIME	TIME	FILE ON F12	DV/V0	STRUE	S-CALC	ERROR	XF(1)=1.1NTPWS
.7700+02	.6000-01	.3042-01	-.9987-04	.1597+02	.1667+02	.4411+01	.4500-01 .1836-15 .6902-04 .1050-06 .1925-18 .529-02 .2855-03 .1738-12 .2311-08
.7700+02	.1100+00	.5648-01	.3001-03	.2048+02	.2603+02	-.8597+01	.8232-01 .1224-12 .4277-15 .5955-02 .4412-03 .2874-10 .3315-04
.7700+02	.1600+00	.8316-01	.1100-02	.4210+02	.3957+02	-.6002+01	.1195+00 .6618-11 .4842-13 .2223-02 .5705-03 .2075-09 .8141-08
.7700+02	.2100+00	.1105+00	.2600-02	.5242+02	.5607+02	.6964+01	.1564+00 .1152-09 .1429-11 .1038-01 .7053-03 .205-04 .8858-04
.7700+02	.2600+00	.1384+00	.4900-02	.6290+02	.7153+02	.1372+02	.1930+00 .1045-08 .1051-10 .1245-01 .8221-03 .5556-07 .5501-04
.7700+02	.3100+00	.1570+00	.7900-02	.7110+02	.8218+02	.1559+02	.2295+00 .6237-08 .1619-06 .1445-01 .9325-03 .2383-04 .6005-04
.7700+02	.3600+00	.1962+00	.170-01	.7743+02	.8634+02	.1152+02	.2657+00 .2759-07 .9425-09 .1641-01 .1038-02 .8014-05 .6647-04
.7700+02	.4100+00	.2260+00	.1840-01	.8247+02	.8524+02	.3363+01	.3018+00 .9735-07 .4105-08 .1831-01 .1130-02 .5000-04 .7165-04
.7700+02	.4600+00	.2564+00	.2170-01	.8640+02	.8216+02	-.4908+01	.3378+00 .2907-06 .1512-01 .2010-01 .1236-03 .5075-05 .7664-04
.7700+02	.5100+00	.2875+00	.2750-01	.8976+02	.8078+02	-.1000+02	.3735+00 .7613-06 .4785-07 .2205-01 .1332-02 .1202-04 .8187-08
.7700+02	.5600+00	.3192+00	.3340-01	.9192+02	.8405+02	-.8552+01	.4101+00 .1809-05 .1332-06 .2390-01 .1426-02 .2388-08 .8622-04
.7700+02	.6100+00	.3515+00	.3840-01	.9408+02	.9264+02	-.1526+01	.4466+00 .3561-05 .3366-04 .5004-02 .5335-03 .1520-02 .8626-04 .9001-08

NONLINEAR THERMOVISCOELASTIC CHARACTERIZATION CODE

N L 0 0 3 D E M O N S T R A T I O N P R O G R A M  
SUMMARY OF SHEAR TEST FOR TEST NO. 2

XF(1),IE=1,INTERMS

TIME	E11 OR E12	DV/V0	STRUE	S-CALC	ERROR	
.7700+02	.4600+00	.4844+00	.4540-01	.9496+02	.1028+02	* .8832+00 .5750-01 .2955-02 .4813-03 .8112-04
						* .8114-05 .7857-06 .2758-01 .1613-02 .9553-04
.7700+02	.4180+00	.5100-01	.9516+02	.1169+03	.2280+02	* .5204+00 .6952-01 .0459-02 .1287-02 .1002-03
						* .1584-04 .1732-05 .2944-01 .1706-02 .1002-03

# NON LINEAR THERMOVISCOELASTIC CHARACTERIZATION CONF PAGE 8

NL003 DEMONSTRATION PROBLEM  
SUMMARY OF SHEAR TEST FOR TEST NO. 3

XF(1),I=1,NTFMS

TEMP TIME E11 OR E12 DV/V0 STRUE S-CALC ERROR

.7700+02	.7000+01	.3554+01	-2.000-03	.1760+02	.1836+02	.4364+01	.5250-01	.1004-03	.2241-06	.4630-00	.6735-12
							.9691-15	.1383-17	.4038-02	.3178-03	.2535-04
.7700+02	.1100+00	.5644+01	.5644+07	.2844+02	.2410+02	-.8378+01	.8241-01	.4057-03	.1098-05	.0848-08	.3521-10
							.1244-12	.4361-15	.5963-02	.4418-03	.3320-04
.7700+02	.1600+00	.8313-01	.5001-03	.4232+02	.3976+02	-.6055+01	.1197+00	.1205-02	.1215-04	.1225-06	.9102-09
							.6815-11	.5013-13	.8280-02	.5908-03	.4151-04
.7700+02	.2100+00	.1104+00	.1200-02	.5632+02	.5660+02	.4978+00	.1570+00	.2685-02	.4445-04	.7552-06	.0672-09
							.1224-08	.1536-11	.1042-01	.7085-03	.4882-04
.7700+02	.2540+00	.1350+00	.2300-02	.6754+02	.7058+02	.4500+01	.1896+00	.4556-02	.1098-03	.2651-05	.4011-07
							.8984-08	.1631-10	.1227-01	.8133-03	.5868-04
.7700+02	.2600+00	.1350+00	.2250-02	.6101+02	.6795+02	.1137+02	.1896+00	.4305-02	.1021-03	.2380-05	.8298-07
							.7693-09	.1369-10	.1204-01	.7757-03	.8067-04
.7700+02	.2700+00	.1350+00	.2100-02	.5696+02	.6209+02	.9003+01	.1896+00	.4244-02	.0536-04	.2103-05	.3822-07
							.6775-09	.1197-10	.1183-01	.7442-03	.8632-04
.7700+02	.2900+00	.1350+00	.2100-02	.5325+02	.5513+02	.3540+01	.1897+00	.4002-02	.8819-04	.1905-05	.3374-07
							.5956-09	.1049-10	.1152-01	.7033-03	.4230-04
.7700+02	.3600+00	.1350+00	.2000-02	.4841+02	.4536+02	-.6290+01	.1897+00	.3835-02	.7784-04	.1580-05	.2784-07
							.4899-09	.8616-11	.1088-01	.6231-03	.3507-04
.7700+02	.4500+00	.1350+00	.1900-02	.4571+02	.4224+02	-.7585+01	.1897+00	.3693-02	.7217-04	.1410-05	.2483-07
							.4370-09	.7687-11	.1036-01	.5660-03	.3029-04
.7700+02	.6500+00	.1350+00	.1800-02	.4274+02	.4389+02	.2590+01	.1898+00	.3533-02	.4600-04	.1233-05	.2171-07
							.8821-08	.6724-11	.0692-02	.4451-03	.2475-04
.7700+02	.6600+00	.1406+00	.1900-02	.5813+02	.5331+02	-.8287+01	.1973+00	.4267-02	.9266-04	.2012-05	.4121-07
							.8428-09	.1722-10	.1041-01	.5680-03	.3287-04

# NONLINEAR THERMOVISCOELASTIC CHARACTERIZATION CODE PAGE 9

N L 0 3 D E M O N S T R A T I O N P R O G R A M  
SUMMARY OF SHEAR TEST FOR TEST NO. 3

TEMP	TIME	E11 OR E12	DV/V0	STRUE	S-CALC	ERROR	XF(1),I=1,NIFRMS
.7700+02	.6800+00	.1520+00	.2900-02	.7070+02	.6796+02	-.3067+01	* .2119+00 .5896-02 .1688-03 .4606-05 .1152-06 * .2760-08 .6306-10 .1152-01 .6557-03 .3921-04
.7700+02	.7100+00	.1692+00	.4100-02	.8082+02	.8066+02	-.1938+00	* .2340+00 .8281-02 .2947-03 .1088-04 .2951-06 * .8128-08 .2218-09 .1303-01 .7605-03 .8650-04
.7700+02	.7600+00	.1965+00	.6400-02	.9190+02	.8955+02	-.2553+01	* .2708+00 .1256-01 .5868-03 .2741-04 .1007-05 * .3655-07 .1316-08 .1552-01 .8064-02 .5573-08
.7700+02	.8100+00	.2283+00	.9300-02	.1308+03	.9050+02	-.9890+01	* .3075+00 .1700-01 .1051-02 .6171-04 .2874-05 * .1322-06 .6078-08 .1787-01 .1038-02 .6326-08
.7700+02	.8600+00	.2588+00	.1270-01	.1075+03	.8932+02	-.1690+02	* .3442+00 .2440-01 .1748-02 .1252-03 .7165-05 * .4051-06 .2272-07 .1953-01 .1152-02 .6980-04
.7700+02	.9100+00	.2899+00	.1640-01	.1131+03	.9114+02	-.1940+02	* .3809+00 .3213-01 .2785-02 .2784-03 .1610-04 * .1093-05 .7356-07 .2154-01 .1263-02 .7597-08
.7700+02	.9600+00	.3217+00	.2050-01	.1175+03	.9884+02	-.1580+02	* .4177+00 .4113-01 .2108-02 .4103-03 .3716-04 * .2647-05 .2006-06 .2351-01 .1369-02 .2163-04
.7700+02	.1010+01	.3540+00	.2450-01	.1211+03	.1128+03	-.6892+01	* .4546+00 .5154-01 .5938-02 .6841-03 .4410-04 * .5931-05 .5486-06 .2585-01 .1472-02 .8707-04
.7700+02	.1060+01	.3870+00	.2860-01	.1238+03	.1287+03	.3930+01	* .4918+00 .6376-01 .2312-02 .1091-02 .1169-03 * .1238-04 .1300-05 .2738-01 .1573-02 .5228-08
.7700+02	.1110+01	.4206+00	.3260-01	.1259+03	.1410+03	.1198+02	* .5292+00 .7689-01 .1134-01 .1679-02 .2036-03 * .2441-04 .2904-05 .2929-01 .1672-02 .9734-04
.7700+02	.1160+01	.4549+00	.3600-01	.1263+03	.1454+03	.1519+02	* .5670+00 .9180-01 .1520-01 .2518-02 .4835-03 * .4629-04 .6189-05 .1121-01 .1770-02 .1024-03

IN 6003 DEMONSTRATION PROGRAM  
SUMMARY OF SHEAR TEST FOR TEST NO. 4

TIME	E11	OR	E12	DV/V0	STRUE	S-CALC	ERROR	X(1),Y(1),NTFPM
7700+02	.5000+00	.2497-01	-.1000-02	.1640+02	.1494+02	-.8931+01	.	.3749-01 .4045-04 .4765-07 .8710-10 .5501-13 .2571-16 .1873-19 .5012-02 .2479-05 .2071-08
7700+02	.1000+00	.5090-01	-.9599-03	.3256+02	.2397+02	-.2638+02	.	.7496-01 .3042-03 .1268-05 .5216-08 .4539-13 .1320-15 .5453-02 .4123-05 .3139-08
7700+02	.1500+00	.7745-01	-.8099-03	.4046+02	.3688+02	-.2544+02	.	.1124+00 .1008-02 .0045-05 .8118-07 .3548-11 .2313-13 .7808-02 .5553-05 .4005-08
7700+02	.2500+00	.1324+00	-.7499-03	.8326+02	.7011+02	-.1578+02	.	.1875+00 .4450-02 .1060-02 .2526-05 .8327-09 .1491-10 .1217-01 .8086-03 .4615-07
7700+02	.3500+00	.1849+00	-.6298-03	.1128+03	.8613+02	-.2365+02	.	.2627+00 .1174-01 .5243-03 .2378-06 .2922-07 .1010-08 .1631-01 .1037-02 .6682-04
7700+02	.4500+00	.2499+00	-.4998-03	.1378+03	.8164+02	-.4076+02	.	.3381+00 .2404-01 .1728-02 .1242-05 .4023-06 .2257-07 .2031-01 .1250-02 .7112-05
7700+02	.5500+00	.3124+00	-.3997-03	.1555+03	.9544+02	-.3864+02	.	.4135+00 .4232-01 .8395-02 .4548-05 .3165-05 .2599-06 .2422-01 .1452-02 .8023-08
7700+02	.6500+00	.3774+00	-.3096-03	.1576+03	.1381+03	-.1759+02	.	.4899+00 .6736-01 .0452-02 .1326-02 .1715-04 .1923-05 .2807-01 .1647-02 .8705-04
7700+02	.7000+00	.4108+00	-.2796-03	.1714+03	.1553+03	-.9436+01	.	.5281+00 .8263-01 .1323-01 .2318-02 .3597-04 .4622-02 .2897-01 .1743-02 .1027-05
7700+02	.7500+00	.4449+00	-.2496-03	.1739+03	.1617+03	-.7050+01	.	.5664+00 .9978-01 .1804-01 .3261-02 .7120-04 .1037-04 .3186-01 .1837-02 .9888-03
7700+02	.8000+00	.4795+00	-.2195-03	.1757+03	.1621+03	-.7712+01	.	.6048+00 .1199+00 .2405-01 .4848-02 .1341-03 .2104-04 .3374-01 .1528-02 .1118-05
7700+02	.8500+00	.5148+00	-.2095-03	.1745+03	.1721+03	-.1394+01	.	.6433+00 .1400+00 .3144-01 .7061-02 .2417-03 .4408-04 .3622-01 .2021-02 .1162-05

# NONLINEAR THERMOVISCOELASTIC CHARACTERIZATION CONF

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## NONLINEAR THERMOVISCOELASTIC CHARACTERIZATION PROBLEM SUMMARY OF SHEAR TEST FOR TEST NO. 5

XF(1)=1,NTPWS

ERROR

S-CALC

STRIE

DV/V0

TIME

TEMP

E11 OR E12

TIME

TEMP

.7700+02	.5000-01	.2463-01	-.2000-02	.1230+02	.1493+02	.2134+02	*	.3748-01	.4074-04	.4383-07	.4676-10	.3468-13
							*	.2541-16	.1847-19	.3011-02	.2478-04	.2070-04
.7700+02	.1300+00	.6640-01	-.1980-02	.4262+02	.3114+02	-.2692+02	*	.9744-01	.6648-03	.4541-05	.3102-07	.1555-09
							*	.7704-12	.3786-14	.6896-02	.4908-03	.3678-04
.7700+02	.2300+00	.1209+00	-.1920-02	.7496+02	.6380+02	-.1698+02	*	.1725+00	.3504-02	.7183-04	.1956-05	.2262-07
							*	.3475-09	.5293-11	.1132-01	.7604-03	.5179-04
.7700+02	.3300+00	.1778+00	-.1830-02	.1107+03	.8523+02	-.2302+02	*	.2476+00	.9940-02	.4016-03	.1622-04	.4117-04
							*	.1594-07	.4929-09	.1549-01	.9927-03	.4446-04
.7700+02	.4300+00	.2373+00	-.1760-02	.1386+03	.8237+02	-.4055+02	*	.3230+00	.2118-01	.1404-02	.9300-04	.8484-05
							*	.2544-06	.1312-07	.1952-01	.1208-02	.7578-04
.7700+02	.5300+00	.2993+00	-.1600-02	.1582+03	.8973+02	-.4327+02	*	.3986+00	.3822-01	.3719-02	.3619-03	.2845-04
							*	.2193-05	.1684-05	.2744-01	.1812-02	.6620-04
.7700+02	.6300+00	.3637+00	-.1480-02	.1716+03	.1296+03	-.2448+02	*	.4746+00	.6189-01	.8229-02	.1054-02	.1184-03
							*	.1266-04	.1342-05	.2729-01	.1608-02	.5601-04
.7700+02	.8000+00	.3969+00	-.1420-02	.1769+03	.1500+03	-.1520+02	*	.5127+00	.7422-01	.1165-01	.1775-02	.2211-03
							*	.2721-04	.3322-05	.2920-01	.1704-02	.1008-03
.7700+02	.7300+00	.4307+00	-.1370-02	.1902+03	.1607+03	-.1085+02	*	.5509+00	.9282-01	.1603-01	.2769-02	.3027-03
							*	.5501-04	.7686-05	.1110-01	.1799-02	.1054-03
.7700+02	.7800+00	.4651+00	-.1320-02	.1821+03	.1621+03	-.1100+02	*	.5892+00	.1112+00	.2155-01	.4180-02	.6682-03
							*	.1055-03	.1654-04	.3298-01	.1892-02	.1099-03
.7700+02	.8300+00	.5002+00	-.1249-02	.1840+03	.1664+03	-.9542+01	*	.6277+00	.1315+00	.2818-01	.6129-02	.1095-02
							*	.1933-03	.3386-04	.3486-01	.1924-02	.1144-03
.7700+02	.8800+00	.5358+00	-.1239-02	.1936+03	.1888+03	.2806+01	*	.6662+00	.1538+00	.3671-01	.8761-02	.1737-02
							*	.3401-03	.6607-04	.3673-01	.2075-02	.1188-03

NL003 DEMONSTRATION PROGRAM  
SUMMARY OF SHEAR TERM FOR TEST NO. 5

TEMP	TIME	E11 OR E12	DV/V0	SYRUE	S-CALC	ERROR	XF(I), I=1,INTERMS
.7700+02	.6300+00	.5721+00	-.1219-02	.1817+03	.2141+03	.1781+02	* .7049+00 .1781+00 .4670-01 .1224-01 .2674-02 * .5771-03 .1235-03 .7859-01 .2165-02 .1231-03
.7700+02	.9700+00	.6016+00	-.1209-02	.1767+03	.1623+03	-.8180+01	* .7359+00 .1901+00 .5603-01 .1577-01 .7706-02 * .8605-03 .1982-03 .4008-01 .2237-02 .1265-03

## NL003 DEMONSTRATION PROBLEM

## REGRESSION COEFFICIENTS ...

I	CO(I)
1	6.28058E+03
2	2.63588E+04
3	-7.50470E+05
4	8.93190E+06
5	-6.32645E+07
6	2.21092E+08
7	-3.00840E+08
8	-2.80744E+05
9	3.80980E+06
10	-1.64232E+07

THERF WFRE 91 EXPERIMENTAL TFST POINTS

THE AVERAGE DEVIATION, XBAR, WAS -.0221

THE STANDARD DEVIATION, STD, WAS .1485

NL003 DEMONSTRATION PROBLEM

SUMMARY OF RULK RESULTS FOR TEST NO. 1

TEMP	TIVE	ENCT	SA-CALC	DIL	DIL-CALC.	ERROR	XF(K), K=1, NRULKS									
.7700+02	.7000-01	.2476-01	.5010+01	.3561-07	-.1350-03	-.3702+06	*	.5010+01	.2510+02	.1250+03	.6300+03	.2076-01				
							*	.6130-03	.1510-04	.4757-06	.2603-01	.6005-03				
							*	.1596-04	.2737-01	.4776-03	.1678-04					
.7700+02	.1100+00	.3879-01	.6187+01	.6001-03	.5389-03	-.1019+02	*	.6187+01	.6702+02	.5407+03	.8402+04	.1879-01				
							*	.1505-02	.5030-04	.2265-05	.8210-01	.1633-02				
							*	.6336-04	.4570-01	.1773-02	.6077-04					
.7700+02	.1600+00	.5624-01	.1112+02	.2000-02	.2331-02	.1653+02	*	.1112+02	.1236+03	.1374+04	.1504+05	.5624-01				
							*	.3163-02	.1779-03	.1001-04	.6206-01	.3535-02				
							*	.1980-03	.7025-01	.1051-02	.2222-03					
.7700+02	.2100+00	.7350-01	.1253+02	.4300-02	.5222-02	.2145+02	*	.1253+02	.1571+03	.1960+04	.2467+05	.7350-01				
							*	.5413-02	.3903-03	.2931-04	.8300-01	.6136-02				
							*	.4515-03	.9453-01	.6955-02	.5118-03					
.7700+02	.2600+00	.9065-01	.1241+02	.8300-02	.9060-02	.9151+01	*	.1241+02	.1501+03	.1912+04	.2373+05	.9065-01				
							*	.8218-02	.7400-03	.6753-04	.1026+00	.9300-02				
							*	.8034-03	.1162+00	.1053-01	.9500-03					
.7700+02	.3100+00	.1075+00	.1205+02	.1300-01	.1304-01	-.4670+00	*	.1205+02	.1453+03	.1752+04	.2112+05	.1075+00				
							*	.1156-01	.1243-02	.1337-03	.1210+00	.1304-01				
							*	.1402-02	.1368+00	.1471-01	.1502-02					
.7700+02	.3600+00	.1242+00	.1155+02	.2100-01	.1952-01	-.7045+01	*	.1155+02	.1335+03	.1502+04	.1701+05	.1242+00				
							*	.1544-01	.1918-02	.2303-03	.1395+00	.1733-01				
							*	.2153-02	.1565+00	.1945-01	.2417-02					
.7700+02	.4100+00	.1409+00	.1180+02	.2950-01	.2644-01	-.1037+02	*	.1180+02	.1301+03	.1641+04	.1936+05	.1400+00				
							*	.1984-01	.2706-02	.3030-03	.1505+00	.2233-01				
							*	.3146-02	.1704+00	.2512-01	.3539-02					
.7700+02	.4600+00	.1575+00	.1238+02	.3000-01	.3471-01	-.1054+02	*	.1238+02	.1533+03	.1897+04	.2300+05	.1575+00				
							*	.2042-01	.3909-02	.6150-03	.1703+00	.2000-01				
							*	.4024-02	.2010+00	.4170-01	.5002-02					
.7700+02	.5100+00	.1743+00	.1310+02	.4070-01	.4442-01	-.8702+01	*	.1310+02	.1715+03	.2247+04	.2903+05	.1743+00				
							*	.3037-01	.5203-02	.9225-03	.1907+00	.1062-01				
							*	.6034-02	.2265+00	.3947-01	.6070-02					
.7700+02	.5600+00	.1911+00	.1330+02	.5950-01	.5513-01	-.7337+01	*	.1330+02	.1770+03	.2355+04	.3133+05	.1911+00				
							*	.3651-01	.6976-02	.1333-02	.2103+00	.4171-01				
							*	.7969-02	.2493+00	.4764-01	.9103-02					
.7700+02	.6100+00	.2001+00	.1208+02	.7020-01	.6670-01	-.4900+01	*	.1208+02	.1600+03	.2130+04	.2700+05	.2001+00				
							*	.4331-01	.9014-02	.1876-02	.2367+00	.4027-01				
							*	.1025-01	.2603+00	.5600-01	.1166-01					

NL003 DEMONSTRATION PROGRAM

SUMMARY OF RULK RESULTS FOR TEST NO. 1

TEMP	TIME	EOCT	SR-CALC	DIL	DIL-CALC.	ERROR	XF(K)*K=1.0RULKS	
.7700+02	.6600+00	.2253+00	.1176+02	.8150-01	.7468-01	-.3458+01	* .1176+02 .1343+02 .1626+04 .1911+05 .2253+00 .5708-01	
							* .5075-01 .1143-01 .2575-02 .2534+00 .1846-01	
							* .1286-01 .2850+00 .6420-01	
.7700+02	.7100+00	.2427+00	.1004+02	.9250-01	.9105-01	-.1572+01	* .1004+02 .1008+03 .1012+04 .1015+05 .2427+00 .6513-01	
							* .5891-01 .1430-01 .3470-02 .2683+00 .1748-01	
							* .1581-01 .2967+00 .7201-01	
.7700+02	.7600+00	.2602+00	.8963+01	.1045+00	.1052+00	.6578+00	* .8963+01 .8013+02 .7200+03 .6453+04 .2602+00 .7407-01	
							* .6772-01 .1742-01 .4586-02 .2446+00 .2108-01	
							* .1927-01 .3113+00 .8101-01	
.7700+02	.8100+00	.2781+00	.8389+01	.1160+00	.1215+00	.4739+01	* .8389+01 .7017+02 .5903+03 .4952+04 .2781+00 .8008-01	
							* .7732-01 .2150-01 .5978-02 .3024+00 .2543-01	
							* .2338-01 .3240+00 .0144-01	
.7700+02	.8600+00	.2961+00	.9657+01	.1275+00	.1429+00	.1211+02	* .9657+01 .9125+02 .9005+03 .8696+04 .2961+00 .8659-01	
							* .8770-01 .2507-01 .7652-02 .3262+00 .0659-01	
							* .2861-01 .3592+00 .1064+00 .3151-01	
.7700+02	.9100+00	.3145+00	.1350+02	.1390+00	.1730+00	.2447+02	* .1350+02 .1822+03 .2440+04 .3321+05 .3145+00 .1132+00	
							* .9889-01 .3110-01 .0780-02 .3509+00 .4074-01	
							* .3559-01 .4119+00 .1295+00	

N L 0 0 3 D E M O N S T R A T I O N P R O B L E M

SUMMARY OF RULK RESULTS FOR TEST NO. 2

TEMP	TIME	EOLT	SR-CALC	DIL	DIL-CALC.	ERROR	XF(K),K=1,NRUI	KS				
.7700+02	.6000-01	.2122-01	-.4475+02	-.9997-04	-.1852-03	.8527+02	*	-.4475+02	.2002+04	-.9961+05	.4010+07	.2122-01
							*	.4502-03	.9553-05	.2027-06	.1356-01	.2878-03
							*	.6107-05	.8670-02	.1840-03	.3904-02	
.7700+02	.1100+00	.3884-01	-.4052+02	.3001-03	.2852-03	-.4935+01	*	-.4052+02	.1642+04	-.6651+05	.2605+07	.3884-01
							*	.1508-02	.5858-04	.2275-05	.2590-01	.1006-02
							*	.3906-04	.1727-01	.6708-03	.2605-04	
.7700+02	.1600+00	.5642-01	-.3676+02	.1100-02	.1217-02	.1060+02	*	-.3676+02	.1351+04	-.8647+05	.1826+07	.5642-01
							*	.3183-02	.1706-03	.1013-04	.3906-01	.2208-02
							*	.1243-03	.2705-01	.1526-02	.8608-04	
.7700+02	.2100+00	.7391-01	-.3557+02	.2600-02	.2631-02	.1176+01	*	-.3557+02	.1265+04	-.4502+05	.1601+07	.7391-01
							*	.5463-02	.4038-03	.2985-04	.5179-01	.3828-02
							*	.2829-03	.3629-01	.2682-02	.1982-01	
.7700+02	.2600+00	.9134-01	-.3444+02	.4900-02	.4601-02	-.6103+01	*	-.3444+02	.1186+04	-.4023+05	.1406+07	.9134-01
							*	.8342-02	.7620-03	.6959-04	.6472-01	.5912-02
							*	.5400-03	.4527-01	.4190-02	.3827-03	
.7700+02	.3100+00	.1087+00	-.3363+02	.7500-02	.7160-02	-.9373+01	*	-.3363+02	.1131+04	-.3804+05	.1279+07	.1087+00
							*	.1182-01	.1285-02	.1397-03	.7767-01	.8445-02
							*	.9182-03	.5549-01	.6033-02	.6559-03	
.7700+02	.3600+00	.1261+00	-.3244+02	.1170-01	.1043-01	-.1082+02	*	-.3244+02	.1052+04	-.3413+05	.1107+07	.1261+00
							*	.1590-01	.2004-02	.2527-03	.9116-01	.1189-01
							*	.1449-02	.6500-01	.8308-02	.1008-02	
.7700+02	.4100+00	.1434+00	-.3067+02	.1640-01	.1459-01	-.1105+02	*	-.3067+02	.9407+03	-.2885+05	.8849+06	.1434+00
							*	.2057-01	.2549-02	.4230-03	.1055+00	.1512-01
							*	.2170-02	.7766-01	.1114-01	.1597-02	
.7700+02	.4600+00	.1608+00	-.2885+02	.2170-01	.1968-01	-.9330+01	*	-.2885+02	.8323+03	-.2401+05	.6927+06	.1608+00
							*	.2585-01	.4156-02	.6683-03	.1285+00	.1937-01
							*	.3115-02	.9029-01	.1452-01	.2334-02	
.7700+02	.5100+00	.1762+00	-.2762+02	.2750-01	.2561-01	-.6880+01	*	-.2762+02	.7627+03	-.76+05	.5817+06	.1762+00
							*	.3177-01	.5662-02	.139-02	.1352+00	.2810-01
							*	.4296-02	.1026+00	.1829-01	.3259-02	
.7700+02	.5600+00	.1959+00	-.2808+02	.3340-01	.3184-01	-.4669+01	*	-.2808+02	.7883+03	-.2213+05	.6215+06	.1959+00
							*	.3836-01	.7513-02	.1471-02	.1479+00	.2807-01
							*	.5674-02	.1117+00	.2188-01	.4285-02	
.7700+02	.6100+00	.2137+00	-.2996+02	.3940-01	.3815-01	-.3161+01	*	-.2996+02	.8976+03	-.2689+05	.8057+06	.2137+00
							*	.4565-01	.9752-02	.2084-02	.1584+00	.3382-01
							*	.7228-02	.1173+00	.2507-01	.5356-02	

AL003 DEMONSTRATION PROGRAM

SUMMARY OF BULK RESULTS FOR TEST NO. 2

TEMP	TIME	EOCT	SR-CALC	DIL	DIL-CALC.	ERROR	XF (K) * K=1. NR/UKS
.7700+02	.6600+00	.2313+00	-.2350+02	.4540-01	.4410-01	-.2471+01	* -.3350+02 * .5368-01 * .8891-02 .1122+04 .1283-01 .1185+00 -.3760+05 .2879-02 .2746-01 .1260+07 .1657+00 .5360-02 .2316+00 .2872-01
.7700+02	.7100+00	.2499+00	-.274+02	.5100-01	.5022-01	-.1533+01	* -.3742+02 * .6245-01 * .1074-01 .1400+04 .1561-01 .1182+00 -.5238+05 .3900-02 .3955-01 .1060+07 .1719+00 .7345-02 .2400+07 .8296-01

NL003 DEMONSTRATION PROGRAM

SUMMARY OF BULK RESULTS FOR TEST NO. 3

TEMP	TIME	E/CCT	SR-CALC	DTL	DIL-CALC	ERROR	XF(K)*K=1.BULK
.7700+02	.7000+01	.2476-01	-.9405+02	-.2000-03	-.2993-03	.4969+02	.8445+04 .1517-04 .3774-02 .2319+06 .7824+08 .2393-04 .2319-05
.7700+02	.1100+00	.3888-01	-.9029+02	.5644-07	-.3334-04	-.5917+05	.8152+04 .2285-05 .2484-03 .6645+08 .1576-01 .9660-05
.7700+02	.1600+00	.5652-01	-.8440+02	.5001-03	.4808-03	-.3855+01	.7064+04 .1021-04 .1094-01 .5572+08 .1387-02 .3208-04
.7700+02	.2100+00	.7419-01	-.8330+02	.1200-02	.1252-02	.4288+01	.6939+04 .4083-03 .1402-01 .4915+08 .2325-01 .7717-04
.7700+02	.2540+00	.8970-01	-.8125+02	.2300-02	.2175-02	-.5429+01	.6501+04 .7218-03 .1766-01 .4380+08 .3581-01 .1421-03
.7700+02	.2600+00	.8971-01	-.8390+02	.2350-02	.2087-02	-.7234+01	.7039+04 .7220-03 .1675-01 .4955+08 .3877-01 .1348-03
.7700+02	.2700+00	.8972-01	-.8453+02	.2200-02	.2067-02	-.6035+01	.7146+04 .7223-03 .1654-01 .5104+08 .3853-01 .1332-03
.7700+02	.2900+00	.8974-01	-.8475+02	.2100-02	.2062-02	-.1832+01	.7182+04 .7228-03 .1648-01 .5188+08 .3885-01 .1327-03
.7700+02	.3600+00	.8976-01	-.8492+02	.2000-02	.2057-02	.2867+01	.7211+04 .7233-03 .1643-01 .5190+08 .3888-01 .1324-03
.7700+02	.4500+00	.8979-01	-.8553+02	.1900-02	.2039-02	.7301+01	.7316+04 .7238-03 .1623-01 .5352+08 .3817-01 .1308-03
.7700+02	.6500+00	.8981-01	-.8730+02	.1800-02	.1984-02	.1021+02	.7421+04 .7243-03 .1667-01 .5352+08 .3817-01 .1308-03
.7700+02	.6600+00	.9337-01	-.8183+02	.1800-02	.2394-02	.2599+02	.6606+04 .8141-03 .1817-01 .4404+08 .4120-01 .1585-03

ALGO3 DEMONSTRATION PROGRAM

SUMMARY OF RULK RESULTS FOR TEST NO. 3

TEMP	TIME	FACT	SR-CALC	DIL	DIL-CALC.	ERROR	VF (K), KET, NRI, UKS					
.7700+02	.6300+00	.1604+01	-.7529+02	.2900+02	.2995+02	.3267+01	*	-.7929+02	.6287+04	-.4985+06	.3953+09	.1004+00
							*	.1007+01	.1011+02	.1018+03	.8541+01	.8557+02
							*	.4573+03	.2055+01	.2062+02	.2070+03	
.7700+02	.6300+00	.1109+00	-.7761+02	.4100+02	.3952+02	-.3603+01	*	-.7761+02	.6024+04	-.4675+06	.3629+09	.1109+00
							*	.1230+01	.1365+02	.1514+03	.5104+01	.5662+02
							*	.6280+03	.2349+01	.2606+02	.2890+03	
.7700+02	.7500+00	.1286+00	-.7496+02	.6400+02	.5924+02	-.7435+01	*	-.7496+02	.5619+04	-.4212+06	.3159+09	.1286+00
							*	.1653+01	.2125+02	.2733+03	.6076+01	.7811+02
							*	.1004+03	.2871+01	.4651+02	.4746+03	
.7700+02	.8100+00	.1462+00	-.7178+02	.9300+02	.8504+02	-.8564+01	*	-.7178+02	.5153+04	-.4699+06	.2655+09	.1462+00
							*	.2135+01	.3127+02	.4573+03	.7134+01	.1042+03
							*	.1526+02	.3450+01	.5085+02	.7442+03	
.7700+02	.8500+00	.1640+00	-.6877+02	.1270+01	.1174+01	-.7546+01	*	-.6877+02	.4729+04	-.3252+06	.2236+09	.1640+00
							*	.2688+01	.4408+02	.7227+03	.8283+01	.1351+01
							*	.2216+02	.4144+01	.6794+02	.1114+02	
.7700+02	.6100+00	.1818+00	-.6712+02	.1640+01	.1546+01	-.5729+01	*	-.6712+02	.4506+04	-.3024+06	.2070+09	.1818+00
							*	.3305+01	.6007+02	.1052+03	.5201+01	.1686+01
							*	.3070+02	.4748+01	.8631+02	.1569+02	
.7700+02	.9600+00	.1927+00	-.6757+02	.2950+01	.1937+01	-.5528+01	*	-.6757+02	.4566+04	-.3085+06	.2085+09	.1927+00
							*	.3988+01	.7565+02	.1551+02	.1016+00	.2029+01
							*	.4053+02	.5170+01	.1032+01	.2062+02	
.7700+02	.1010+01	.2178+00	-.7006+02	.2450+01	.2323+01	-.5191+01	*	-.7006+02	.4909+04	-.3439+06	.2410+09	.2178+00
							*	.4745+01	.1074+01	.2252+02	.1081+00	.2355+01
							*	.5130+02	.5365+01	.1169+01	.2546+02	
.7700+02	.1060+01	.2361+00	-.7368+02	.2860+01	.2710+01	-.5261+01	*	-.7368+02	.5429+04	-.4000+06	.2907+09	.2361+00
							*	.5575+01	.1316+01	.3109+02	.3130+00	.2669+01
							*	.8301+02	.5410+01	.1277+01	.3016+02	
.7700+02	.1110+01	.2546+00	-.7671+02	.3260+01	.3151+01	-.3334+01	*	-.7671+02	.5985+04	-.4515+06	.3463+09	.2546+00
							*	.6983+01	.1651+01	.4208+02	.1182+00	.3011+01
							*	.7466+02	.5490+01	.1398+01	.3559+02	
.7700+02	.1160+01	.2734+00	-.7837+02	.3600+01	.3608+01	.2718+01	*	-.7837+02	.6142+04	-.4813+06	.3772+09	.2734+00
							*	.7476+01	.2064+01	.5590+02	.1249+00	.3415+01
							*	.9337+02	.5704+01	.1560+01	.4268+02	

N L 0 0 3 D E M O N S T R A T I O N P R O B L E M

S U M M A R Y O F R U L K R E S U L T S F O R T E S T N O . 4

TIME	TIME	FACT	SR-CALC	OIL	DIL-CALC.	ERROR	YF(K)*K=1*NR/LMS				
.7700+02	.5000+01	.1768-01	-.4923+03	-.1000-02	-.1034-02	.3390+01	* -.4923+03	.2424+06	-.1193+09	.5878+11	.1768-01
							* .3124-03	.5522-05	.0761-07	.1286-03	.2275-05
							* .4018-07	.9359-06	.1654-07	.2924-06	
.7700+02	.1000+00	.3536-01	-.4861+03	-.9599-03	-.9366-03	-.2428+01	* -.4861+03	.2363+06	-.1148+09	.5582+11	.3536-01
							* .1251-02	.4822-04	.1564-05	.2739-03	.9685-05
							* .3425-06	.2121-05	.7501-07	.2653-08	
.7700+02	.1500+00	.5309-01	-.4804+03	-.8999-03	-.8597-03	-.4472+01	* -.4804+03	.2308+06	-.1106+09	.5325+11	.5309-01
							* .2818-02	.1806-03	.7942-05	.4352-03	.2310-04
							* .1227-05	.3568-05	.1854-06	.1006-07	
.7700+02	.2500+00	.6872-01	-.4711+03	-.7499-03	-.7494-03	-.6180-01	* -.4711+03	.2219+06	-.1045+09	.4524+11	.6872-01
							* .7870-02	.6982-03	.2154-04	.7584-03	.7083-04
							* .6284-05	.7186-05	.2375-06	.5656-07	
.7700+02	.3500+00	.1247+00	-.4611+03	-.6298-03	-.6663-03	.5796+01	* -.4611+03	.2126+06	-.0801+09	.4510+11	.1247+00
							* .1555-01	.1539-02	.2418-03	.1240-02	.1547-03
							* .1920-04	.1232-04	.1539-05	.1518-06	
.7700+02	.4500+00	.1811+00	-.4489+03	-.4099-03	-.5669-03	.1304+02	* -.4489+03	.2015+06	-.0087+09	.4061+11	.1811+00
							* .2597-01	.4104-02	.2743-03	.1810-02	.2016-03
							* .4690-04	.2032-04	.3275-05	.5277-06	
.7700+02	.5500+00	.1561+00	-.4446+03	-.3897-03	-.4288-03	.1004+02	* -.4446+03	.1977+06	-.0789+09	.3907+11	.1561+00
							* .3925-01	.7777-02	.1541-02	.2323-02	.4603-03
							* .9120-04	.2725-04	.5368-05	.1066-06	
.7700+02	.6500+00	.2457+00	-.4506+03	-.3096-03	-.2550-03	-.1765+02	* -.4506+03	.2031+06	-.0150+09	.4123+11	.2457+00
							* .5556-01	.1310-01	.3027-02	.2603-02	.6135-03
							* .1446-03	.2874-04	.4774-05	.1597-06	
.7700+02	.7500+00	.2549+00	-.4540+03	-.2796-03	-.1408-03	-.4965+02	* -.4540+03	.2061+06	-.0355+09	.4247+11	.2549+00
							* .6491-01	.1654-01	.4213-02	.2720-02	.6031-03
							* .1766-03	.2505-04	.7401-05	.1895-06	
.7700+02	.8500+00	.2740+00	-.4552+03	-.2496-03	.1030-04	-.1041+03	* -.4552+03	.2072+06	-.0434+09	.4264+11	.2740+00
							* .7507-01	.2057-01	.5636-02	.2889-02	.7915-03
							* .2169-03	.3046-04	.8345-05	.2286-06	
.7700+02	.9500+00	.2934+00	-.4553+03	-.2195-03	.2025-03	-.1922+03	* -.4553+03	.2073+06	-.0436+09	.4264+11	.2934+00
							* .8608-01	.2526-01	.7410-02	.3052-02	.9072-03
							* .2662-03	.3259-04	.9561-05	.2805-06	
.7700+02	.0500+00	.3140+00	-.4593+03	-.2095-03	.3949-03	-.2885+03	* -.4593+03	.2110+06	-.0661+09	.4451+11	.3140+00
							* .9796-01	.3046-01	.5597-02	.3168-02	.9914-03
							* .3103-03	.3206-04	.1003-05	.3140-06	

NLOO3 DEMONSTRATION PROBLEM

SUMMARY OF RULK RESULTS FOR TEST NO. 1

TEMP	TIME	ENCT	SR-CALC	DIL	DIL-CALC. ERROR	XF(K),K=1,NRULKS	
.7700+02	.5000+01	.1767-01	-.9923+03	-.2000-02	-.2098-02	.4900+01	* -.9923+03 .9846+06 -.0769+09 .9694+12 .1767-01 * .3122-03 .5517-05 .9748-07 .8668-06 .1532-07 * .2706-09 .4252-10 .7514-12 .1328-13
.7700+02	.1300+00	.4599-01	-.9804+03	-.1980-02	-.1883-02	-.4873+01	* -.5904+03 .9611+06 -.0423+09 .9238+12 .4599-01 * .2115-02 .9726-04 .4473-05 .2541-05 .1168-06 * .5373-08 .1404-09 .6455-11 .2968-12
.7700+02	.2300+00	.8157-01	-.9705+03	-.1220-02	-.1721-02	-.1034+02	* -.9705+03 .9418+06 -.0140+09 .8870+12 .8157-01 * .6653-02 .5427-03 .4427-04 .4975-05 .4058-06 * .3310-07 .3035-09 .2475-10 .2019-11
.7700+02	.3300+00	.1175+00	-.9594+03	-.1030-02	-.1612-02	-.1192+02	* -.9594+03 .9205+06 -.0811+09 .8473+12 .1175+00 * .1380-01 .1621-02 .1904-03 .8002-05 .8400-06 * .1104-06 .5451-08 .6404-10 .7523-11
.7700+02	.4300+00	.1538+00	-.9463+03	-.1760-02	-.1526-02	-.1326+02	* -.9463+03 .8955+06 -.0474+09 .8018+12 .1538+00 * .2366-01 .3639-02 .5597-03 .1105-04 .1838-05 * .2827-06 .9282-09 .1428-09 .2196-10
.7700+02	.5300+00	.1907+00	-.9395+03	-.1500-02	-.1487-02	-.7022+01	* -.9395+03 .8827+06 -.0293+09 .7761+12 .1907+00 * .3635-01 .6930-02 .1321-02 .1585-04 .3022-05 * .5761-06 .1318-08 .2512-09 .4790-10
.7700+02	.6300+00	.2261+00	-.9440+03	-.1480-02	-.1495-02	.1010+01	* -.9440+03 .8911+06 -.0412+09 .7941+12 .2261+00 * .5203-01 .1187-01 .2707-02 .1813-04 .4138-05 * .9435-06 .1442-08 .3288-09 .7500-10
.7700+02	.6800+00	.2471+00	-.9474+03	-.1420-02	-.1493-02	.5154+01	* -.9474+03 .8975+06 -.0502+09 .8056+12 .2471+00 * .6104-01 .1508-01 .3726-02 .1898-04 .4691-05 * .1159-05 .1459-08 .3604-09 .8905-10
.7700+02	.7300+00	.2662+00	-.9493+03	-.1370-02	-.1472-02	.7464+01	* -.9493+03 .9013+06 -.0556+09 .8123+12 .2662+00 * .7087-01 .1897-01 .5023-02 .2006-04 .5339-05 * .1421-05 .1511-08 .8023-09 .1071-09
.7700+02	.7800+00	.2855+00	-.9496+03	-.1320-02	-.1427-02	.8148+01	* -.9496+03 .9017+06 -.0563+09 .8131+12 .2855+00 * .8153-01 .2328-01 .6647-02 .2146-04 .6127-05 * .1750-05 .1613-08 .8605-09 .1315-09
.7700+02	.8300+00	.3050+00	-.9506+03	-.1269-02	-.1369-02	.7869+01	* -.9506+03 .9077+06 -.0591+09 .8166+12 .3050+00 * .9305-01 .2838-01 .8659-02 .2268-04 .6022-05 * .2111-05 .1688-08 .5149-09 .1571-09
.7700+02	.8800+00	.3247+00	-.9578+03	-.1239-02	-.1326-02	.6991+01	* -.9578+03 .9173+06 -.0785+09 .8414+12 .3247+00 * .1055+00 .3425-01 .1112-01 .2249-04 .7305-05 * .2372-05 .1658-08 .5060-09 .1643-09

NON LINEAR THERMOVISCOELASTIC CHARACTERIZATION CODE

AL003 DEMONSTRATION PROBLEM

SUMMARY OF BULK RESULTS FOR TEST NO. 5

TEMP	TIME	EXCT	SR-CALC	DIL	DIL-CALC.	ERROR	XF(K),K=1,ARULKS
.7700+02	.9300+00	.3446+00	-.9667+03	-.1219-02	-.1272-02	.4318+01	.0344+06 .4004-01 .1304-04 .0768-09 .8772+12 .2184-04 .1643-06 .3446+00 .7526-05
.7700+02	.9700+00	.3607+00	-.9550+03	-.1309-02	-.1102-02	-.8891+01	.9121+06 .4603-01 .1693-01 .1828-04 .6593-09 .8319+12 .2568-04 .2379-06 .3607+00 .0262-05

## NONLINEAR THERMOVISCOELASTIC CHARACTERIZATION CODE

## NL003 DEMONSTRATION PROGRAM

## REGRESSION COEFFICIENTS ...

I	CO(I)
1	6.73311-06
2	1.30469-0A
3	8.23299-12
4	-3.49560-16
5	7.55943-03
6	-4.72075-02
7	1.10045-01
8	-5.12720-02
9	1.57065-02
10	3.61805-02
11	2.68790+00
12	-5.81638-02
13	1.20213+00
14	-1.59303+00

## THEME WERE 91 EXPERIMENTAL TEST POINTS

THE AVERAGE DEVIATION, XBAR, WAS -.0063

THE STANDARD DEVIATION, STD, WAS .0793

DATA CARDS IGNORED - FIRST IS LISTED BELOW

15 JUN 73 13:44:40 PAGE 3

15 JUN 73 00:00:02.520

VICOMAY-425772-1-100

SI FOR: M003-1003  
DATE, TIME, LEVEL OF OUTPUT ELEMENT: 15 JUN 73 13:44(n.)  
FORTRAN V3. ISO VERSION 2.6

# MAIN PROGRAM

## STORAGE USED (BLOCK, NAME, LENGTH)

0001 \*COBF 003175  
0000 \*DATA 012720  
0002 \*PLANK 001000  
0003 \*PUT 007034

## EXTERNAL REFERENCES (BLOCK, NAME)

0004 ICMIT  
0005 PARM  
0006 BUFFER  
0007 UERR  
0010 LPPAS  
0011 MDPUS  
0012 M013  
0013 M023  
0014 M003  
0015 ALCS  
0016 EXP  
0017 KEAPAS  
0020 INSGRT  
0021 LEXP  
0022 MEXPAS  
0023 MDPUS  
0024 MDPUS  
0025 MSTOP3

## STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0000	012057	IF	0001	000567	10L	0001	000370	100L	0001	001772	1456	0001	002003	1018
0001	000004	1016R	0001	002020	1056	0001	000023	10316	0001	002075	1456	0001	002197	1100
0001	002252	1120G	0001	002234	1124G	0001	002237	11316	0001	002260	1456	0001	002315	1150
0001	002337	1172G	0001	002337	1174G	0001	000547	12L	0001	002340	1203G	0001	000031	1210
0001	002362	1210G	0001	002375	1214G	0001	002513	1242G	0001	002515	1205G	0001	002527	1200
0001	002606	1271G	0001	002617	1277G	0001	012066	13F	0001	002617	1301G	0001	002652	1314
0001	000052	133G	0001	002715	1334G	0001	002737	1353G	0001	002737	1355G	0001	002751	1345G
0001	002762	1373G	0001	002762	1375G	0001	012073	14F	0001	002775	1403G	0001	003000	1407G
0001	000064	1416	0001	003051	1436G	0001	003150	1442G	0001	000076	147G	0001	012075	15F
0001	000110	155G	0001	000132	166G	0001	000641	18L	0001	001020	19L	0001	012060	2F
0001	000754	20L	0001	001631	200L	0001	000160	202G	0001	000742	21L	0001	000177	215G
0001	000214	222G	0001	000270	247G	0001	000302	256G	0001	000303	274G	0001	000225	31
0000	012077	30F	0001	000355	300G	0001	012124	31F	0001	000303	310G	0001	000225	31
0000	012134	32F	0001	000400	320G	0001	012144	33F	0001	000303	310G	0001	000225	31
0001	000427	350G	0001	012062	4F	0001	012202	40F	0001	000303	310G	0001	000225	31
0001	000537	412G	0001	012213	42F	0001	000604	427G	0001	000303	310G	0001	000225	31
0001	000602	444G	0001	000703	451G	0001	000771	470G	0001	000303	310G	0001	000225	31
0001	001002	506G	0001	001143	526G	0001	002054	530L	0001	001170	545G	0001	001223	55L
0001	001077	550L	0001	001242	556G	0001	002054	530L	0001	003013	545L	0001	001275	571G



VRONAV, 425772, 1, 100

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00104 32* 1 TEMP, RATE, DT, STRESS, OIL, T, E11, F22, E13, E12,
00104 33* 2 STRHE, DRI, D22, DRI2, INV1, INV2, INV3, NORMF,
00104 34* 3 NORM, FOCY
C
00104 35* DATA JEND/END//
C
00104 36* 00105 36* DOUBLE PRECISION A1, A2, INV1, INV2, INV3, NOR-E, NORM, FOCY
C
00104 37* 00107 37* REAL INT1, INT2, TA, IP
C
00104 38* 00108 38* DYNAMICALLY ALLOCATE ORUM SPACE.
C
00104 39* 00109 39* CALL TCHMT1(DRUM, 11, 75, WORK1)
00104 40* 00110 40* CALL TCHMT1(DRUM, 12, 25, WORK2)
C
00104 41* 00111 41* IELAG = 0
00104 42* 00112 42* IPA = 0
C
00104 43* 00113 43* NI = 1
00104 44* 00114 44* ASSIGN TAPE UNIT CPG.
C
00104 45* 00115 45* IF (NI.NE.0)
C
00104 46* 00116 46* READ(5,1) (NAME(I), I=1, 20)
00104 47* 00117 47* READ(5,2) A, Z
00104 48* 00118 48* READ(5,75) (IFG(I), I=1, 7)
00104 49* 00119 49* READ(5,75) (IPF(I), I=1, 16)
C
00104 50* 00120 50* I, PUT NORM SELECTION AND EXPONENTS.
C
00104 51* 00121 51* READ(5,75) (IFM(I), I=1, 6)
00104 52* 00122 52* READ(5,2) (VNM(I), I=1, 5)
C
00104 53* 00123 53* INPUT POWER LAW EXPONENTS AND COEFFICIENTS.
00104 54* 00124 54* READ(5,75) NPL
00104 55* 00125 55* READ(5,2) (P(I), I=1, 16)
C
00104 56* 00126 56* CALL PACTL(IPG, NAME)
00104 57* 00127 57* WRITE(6,22) A, Z
00104 58* 00128 58* WRITE(6,40) (I, P(I), P(I), IFG(I), I=1, 7)
00104 59* 00129 59* WRITE(6,42) (I, IPF(I), I=1, 16)
00104 60* 00130 60* WRITE(6,44) (I, IFM(I), X(I), I=1, 6)
C
00104 61* 00131 61* NAT = 0
00104 62* 00132 62* NAT = NAT + 1
00104 63* 00133 63* READ(5,4) TSUFT(NAT), AT(NAT), IAST
00104 64* 00134 64* IF (LAST.EQ.0) C TO 1
00104 65* 00135 65* CALL PACTL(IPG, NAME)
00104 66* 00136 66* WRITE(6,30) NAT
00104 67* 00137 67* WRITE(6,31) (I, AT(I), TSUFT(I), I=1, NAT)
C
00104 68* 00138 68* COMPUTE SLOPE, N, AT EACH INPUT POINT.
00104 69* 00139 69* DO 5 I=2, NAT
00104 70* 00140 70* 5

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VRONAY-025772.1.100

00260 020 D(I) = (LOG(AT(I)) - LOG(AT(I-1))) / (TSMT(I) - TSMT(I-1))

00261 930 CONTINUE

00262 940 D(I) = D(I)

00263 950 C

00264 960 NTEST = 0

00265 970 RE-AND 11

00266 980 RE-AND 12

00267 990 LIF = 0

00270 1000 CALL PARML(IPR, NAME)

00271 1010 WRITE(6,33)

00272 1020 DO 110 I=1,10

00273 1030 R(I) = 0.0

00274 1040 DO 105 J=1,100

00275 1050 X(I,J,K) = 0.0

00276 1060 X(I,J,K) = 0.0

00277 1070 X(I,J,K) = 0.0

00278 1080 X(I,J,K) = 0.0

00279 1090 X(I,J,K) = 0.0

00280 1100 X(I,J,K) = 0.0

00281 1110 X(I,J,K) = 0.0

00282 1120 X(I,J,K) = 0.0

00283 1130 X(I,J,K) = 0.0

00284 1140 X(I,J,K) = 0.0

00285 1150 X(I,J,K) = 0.0

00286 1160 X(I,J,K) = 0.0

00287 1170 X(I,J,K) = 0.0

00288 1180 X(I,J,K) = 0.0

00289 1190 X(I,J,K) = 0.0

00290 1200 X(I,J,K) = 0.0

00291 1210 X(I,J,K) = 0.0

00292 1220 X(I,J,K) = 0.0

00293 1230 X(I,J,K) = 0.0

00294 1240 X(I,J,K) = 0.0

00295 1250 X(I,J,K) = 0.0

00296 1260 X(I,J,K) = 0.0

00297 1270 X(I,J,K) = 0.0

00298 1280 X(I,J,K) = 0.0

00299 1290 X(I,J,K) = 0.0

00300 1300 X(I,J,K) = 0.0

00301 1310 X(I,J,K) = 0.0

00302 1320 X(I,J,K) = 0.0

00303 1330 X(I,J,K) = 0.0

00304 1340 X(I,J,K) = 0.0

00305 1350 X(I,J,K) = 0.0

00306 1360 X(I,J,K) = 0.0

00307 1370 X(I,J,K) = 0.0

00308 1380 X(I,J,K) = 0.0

00309 1390 X(I,J,K) = 0.0

00310 1400 X(I,J,K) = 0.0

00311 1410 X(I,J,K) = 0.0

00312 1420 X(I,J,K) = 0.0

00313 1430 X(I,J,K) = 0.0

00314 1440 X(I,J,K) = 0.0

00315 1450 X(I,J,K) = 0.0

00316 1460 X(I,J,K) = 0.0

00317 1470 X(I,J,K) = 0.0

00318 1480 X(I,J,K) = 0.0

00319 1490 X(I,J,K) = 0.0

00320 1500 X(I,J,K) = 0.0

00321 1510 X(I,J,K) = 0.0

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00361 1520 LINP = LINE + 1
00362 1530 IF (LINE.LF.50) GO TO 34
00363 1540 CALL MACPL(TPG, NAMP )
00364 1550 WRITE(6,33)
00365 1560 LINF = 0
00366 1570 CONTINUE
00367 1580 34 WRITE(6,35) NTFST,ITFCT,NBP,NOTE,TEMP,PRES,TEMP(I)
00368 1590 C
00369 1600 C COMPUTE THE REDUCED TIME, TR.
00370 1610 C
00371 1620 DO A IEN1,NBP
00372 1630 IF (I.NE.1) GO TO 9
00373 1640 *ADJUSTIC*
00374 1650 IF (TEMP(I).EQ.TEMP(I-1)) GO TO 10
00375 1660 DO 11 J=1,NAT
00376 1670 IF (TEMP(I).LT.TSHIFT(J)) GO TO 12
00377 1680 11 CONTINUE
00378 1690 12 AVGAT = ( EXPLOG(AT(J-1)) + D(J)*TEMP(I) - TSHIFT(J-1) )
00379 1700 10 TR(I) = TR(I-1) + DT(I)/AVGAT
00380 1710 C
00381 1720 CONTINUE
00382 1730 C
00383 1740 IF TEMP IS CONSTANT READ 10TH THRU 60TH NCRVS, OTHERWISE
00384 1750 COMPUTE TRPV BASED ON THE REQUIRED TIME, TR.
00385 1760 C
00386 1770 IF (KTEMP.FO.2) GO TO 1A
00387 1780 C
00388 1790 C IF A CONSTANT TEMP TEST, MULTIPLY THE PTH NOTM BY (1/AT)exp1/P.
00389 1800 C
00390 1810 DO 60 M=1,6
00391 1820 XP = 1.0/(10*AV)
00392 1830 DO 60 I=1,NBP
00393 1840 NORM(I,M) = NORM(M,1)/(1./AVGAT)exp1
00394 1850 CONTINUE
00395 1860 GO TO 1B
00396 1870 1B CONTINUE
00397 1880 C
00398 1890 DO 20 M=1,6
00399 1900 XP = 1.0*(10*AV)
00400 1910 XG = 10.*AV
00401 1920 DO 20 I=1,NBP
00402 1930 DTG = TP(I) - TR(I-1)
00403 1940 A1 = NARS(INV2(I))
00404 1950 A2 = NARS(INV2(I-1))
00405 1960 *ADJUSTIC*
00406 1970 IF (A1.EQ.A2) GO TO 21
00407 1980 NORM(M,1) = NORM(M,1-1) + (A1exp1-A2exp1)/(XP*(A1-A2)/NTP )
00408 1990 GO TO 20
00409 2000 CONTINUE
00410 2010 21
00411 2020 20
00412 2030 C
00413 2040 DO 22 M=1,6
00414 2050 XP = 10.*AV
00415 2060 DO 22 I=1,NBP
00416 2070 NORM(M,1) = NORM(M,1)exp1
00417 2080 CONTINUE
00418 2090 22
00419 2100 C

```



E-31

E-32





[illegible]

CLASS REFERENCE BY SOURCE NUMBER

SINGLE AND COLLETH STRINGS-----  
C410 : 011, 0112  
C411 : 0105

[illegible]

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EOCT	: 0103	0104	0107	0654	0753	01151	01225	01226	01227	01230	01231	01233	01234	01235	01236	01237
EAP	: 01424	01231	01232	01233	01234	01235	01236									
E11	: 0103	0104	0107	0510	0512	0654	0753	01004	01151	01332						
E12	: 0103	0104	0107	0510	0512	0654	0753	01004	01151	01332						
E22	: 0103	0104	0107	0510	0512	0654	0753	01004	01151	01332						
F33	: 0103	0104	0107	0510	0512	0654	0753	01004	01151	01332						
F	: 0103	0104	0107	0510	0512	0654	0753	01004	01151	01332						
I	: 0103	0104	0107	0510	0512	0654	0753	01004	01151	01332						
IFF	: 0103	0104	0107	0510	0512	0654	0753	01004	01151	01332						
IFG	: 0103	0104	0107	0510	0512	0654	0753	01004	01151	01332						
IFLAG	: 0103	0104	0107	0510	0512	0654	0753	01004	01151	01332						
IFN	: 0103	0104	0107	0510	0512	0654	0753	01004	01151	01332						
IFPUT	: 0104	0565	0375	0604												
I-T1	: 0110	0565	0375	0604												
I-T12	: 0110	0565	0375	0604												
I-T2	: 0110	0565	0375	0604												
I-T3	: 0110	0565	0375	0604												
I-T4	: 0110	0565	0375	0604												
I-T5	: 0110	0565	0375	0604												
I-T6	: 0110	0565	0375	0604												
I-T7	: 0110	0565	0375	0604												
I-T8	: 0110	0565	0375	0604												
I-T9	: 0110	0565	0375	0604												
I-T10	: 0110	0565	0375	0604												
I-T11	: 0110	0565	0375	0604												
I-T12	: 0110	0565	0375	0604												
I-T13	: 0110	0565	0375	0604												
I-T14	: 0110	0565	0375	0604												
I-T15	: 0110	0565	0375	0604												
I-T16	: 0110	0565	0375	0604												
I-T17	: 0110	0565	0375	0604												
I-T18	: 0110	0565	0375	0604												
I-T19	: 0110	0565	0375	0604												
I-T20	: 0110	0565	0375	0604												
I-T21	: 0110	0565	0375	0604												
I-T22	: 0110	0565	0375	0604												
I-T23	: 0110	0565	0375	0604												
I-T24	: 0110	0565	0375	0604												
I-T25	: 0110	0565	0375	0604												
I-T26	: 0110	0565	0375	0604												
I-T27	: 0110	0565	0375	0604												
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I-T32	: 0110	0565	0375	0604												
I-T33	: 0110	0565	0375	0604												
I-T34	: 0110	0565	0375	0604												
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I-T36	: 0110	0565	0375	0604												
I-T37	: 0110	0565	0375	0604												
I-T38	: 0110	0565	0375	0604												
I-T39	: 0110	0565	0375	0604												
I-T40	: 0110	0565	0375	0604												
I-T41	: 0110	0565	0375	0604												
I-T42	: 0110	0565	0375	0604												
I-T43	: 0110	0565	0375	0604												
I-T44	: 0110	0565	0375	0604												
I-T45	: 0110	0565	0375	0604												
I-T46	: 0110	0565	0375	0604												
I-T47	: 0110	0565	0375	0604												
I-T48	: 0110	0565	0375	0604												
I-T49	: 0110	0565	0375	0604												
I-T50	: 0110	0565	0375	0604												
I-T51	: 0110	0565	0375	0604												
I-T52	: 0110	0565	0375	0604												
I-T53	: 0110	0565	0375	0604												
I-T54	: 0110	0565	0375	0604												
I-T55	: 0110	0565	0375	0604												
I-T56	: 0110	0565	0375	0604												
I-T57	: 0110	0565	0375	0604												
I-T58	: 0110	0565	0375	0604												
I-T59	: 0110	0565	0375	0604												
I-T60	: 0110	0565	0375	0604												
I-T61	: 0110	0565	0375	0604												
I-T62	: 0110	0565	0375	0604												
I-T63	: 0110	0565	0375	0604												
I-T64	: 0110	0565	0375	0604												
I-T65	: 0110	0565	0375	0604												
I-T66	: 0110	0565	0375	0604												
I-T67	: 0110	0565	0375	0604												
I-T68	: 0110	0565	0375	0604												
I-T69	: 0110	0565	0375	0604												
I-T70	: 0110	0565	0375	0604												
I-T71	: 0110	0565	0375	0604												
I-T72	: 0110	0565	0375	0604												
I-T73	: 0110	0565	0375	0604												
I-T74	: 0110	0565	0375	0604												
I-T75	: 0110	0565	0375	0604												
I-T76	: 0110	0565	0375	0604												
I-T77	: 0110	0565	0375	0604												
I-T78	: 0110	0565	0375	0604												
I-T79	: 0110	0565	0375	0604												
I-T80	: 0110	0565	0375	0604												
I-T81	: 0110	0565	0375	0604												
I-T82	: 0110	0565	0375	0604												
I-T83	: 0110	0565	0375	0604												
I-T84	: 0110	0565	0375	0604												
I-T85	: 0110	0565	0375	0604												
I-T86	: 0110	0565	0375	0604												
I-T87	: 0110	0565	0375	0604												
I-T88	: 0110	0565	0375	0604												
I-T89	: 0110	0565	0375	0604												
I-T90	: 0110	0565	0375	0604												
I-T91	: 0110	0565	0375	0604												
I-T92	: 0110	0565	0375	0604												
I-T93	: 0110	0565	0375	0604												
I-T94	: 0110	0565	0375	0604												
I-T95	: 0110	0565	0375	0604												
I-T96	: 0110	0565	0375	0604												
I-T97	: 0110	0565	0375	0604												
I-T98	: 0110	0565	0375	0604												
I-T99	: 0110	0565	0375	0604												
I-T100	: 0110	0565	0375	0604												

[illegible]

LABELS-----		
1:	0117	01474
2:	0125	0153
3:	0231	0237
4:	0232	01476
5:	0255	0261
7:	0130	
8:	0401	0422
9:	0401	0411
10:	0402	0421
11:	0411	0416
12:	0414	0423
13:	01500	
14:	01501	
15:	01502	
18:	0424	0442
19:	0431	0503
20:	0453	0450
21:	0456	0462
22:	0457	0500
32:	0257	01503
31:	0245	01504
32:	0174	01505
33:	0271	01506
34:	0362	0370
35:	0371	01507
40:	0200	01510

[illegible]

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## APPENDIX F

### SUBPROGRAMS

#### 1.0 INTRODUCTION

This appendix lists the additional subprograms called for in codes NL001, NL002, NL003, POST, and LINVIS. These routines are used for page counting, headings and matrix inversion and are common to these codes. Since these subroutines need no input from the user only the listings are presented.

15 JUN 73 09:24:50 PAGE 3  
15 JUN 73 00:00:00.000

LI FOR PAGE: PACH  
DATE, TIME, LEVEL OF OUTPUT ELEMENT: 15 JUN 73 09:24:50  
FORTRAN V: ISO VERSION 2.0

SUBROUTINE PAGHL ENTRY POINT 000035

STORAGE USED (BLOCK, NAME, LENGTH)

0001 \*CODE 000047  
0000 \*DATA 000045  
0002 \*BLANK 000000

EXTERNAL REFERENCES (BLOCK, NAME)

0003 NEND35  
0004 NIG25  
0005 NIG15  
0006 NERR35

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

CODE 000001 IF 0001 000020 1726 0000 000027 2F 0000 Y 000000 I

LINE	C	SUBROUTINE	PAGHL (PG, TITLE)
00100	1*	C	
00101	2*	C	
00102	3*	C	
00103	4*	C	SUBROUTINE PULLS UP A NEW PAGE FOR NL002, INCREMENTS AND NUMBERS
00104	5*	C	IT, SKIPS TWO LINES THEN WRITES AN RD COLUMN TITLE IN THE CENTER
00105	6*	C	OF THE PAGE.
00106	7*	C	
00107	8*	C	
00108	9*	C	DEFINITION TITLE(20)
00109	10*	C	PG = PG + 1
00110	11*	C	WRITE(6,1) IPG
00111	12*	C	WRITE(6,2) (TITLE(I), I=1,20)
00112	13*	C	
00113	14*	C	1 FORMAT(1H, 'NONLINEAR', THE MOVIE SCOFFLASH
00114	15*	C	11 C CHARACTERIZATION CODE, T120, *PAGE*,
00115	16*	C	214, // )
00116	17*	C	2 FORMAT(1H, 30X, 20A4)
00117	18*	C	
00118	19*	C	RETURN
00119	20*	C	END

\* CROSS REFERENCE BY SEQUENCE NUMBER \*

NAME :  
IPG : 0100 0104 0105  
PAGHL : 0101  
TITLE : 0101 0103 0110

VIETNAM. ΔΥ. 46. 77. 1. 170

WI FOR REG. REF.

TIME LEVEL OF CRIPPLE FLUMENT: 15 JUN 73 09:24 (00)

FORTRAN V: ISN VERSION 2.0

SUBROUTINE REGR  
ENTRY POINT C00257

STORAGE USED (BLOCK, NAME, LENGTH)

Судебная коллегия по уголовным делам Верховного Суда Российской Федерации

0960  
•EAL:  
000774

000000  
#HLAFLK 000000

EXTERNAL REFERENCES (BLOCK, NAME)

0003 Page: 1

0000  
0004  
0004  
0004

CU05 N4NLS

0006 N1025

6667 11E8833

STORAGE ASSIGMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

[illegible]

00100	C	SUBROUTINE DEGR( NDEGS, ANS, COS, RS )
00101	C	
00101	C	PREFMULTIPLIES THE VECTOR AA BY R INVERSE TO FORM THE
00101	C	REGRESSION COEFFICIENTS.
00101	C	
00101	C	
00103	C	DIMENSION RR(14), CC(14), RI(14,14)
00103	A	DIMENSION ABS(14), COS(14), PC(14,14)
00103	A	SINGLE PRECISION AA, CC, R, COW
00105	C	300 FORMAT(1H, //, 4CX, /CON = ', IPE12.4 )
00107	C	410 FORMAT(1H, 20(/), 40X, /I NV F R S F F A I L D O N R O W
00107	C	, 16 )
00107	C	
00107	C	LOAD INTO DOUBLE PRECISION ARRAYS FOR INVERSION.
00107	C	
00107	C	
00110	C	DO 100 I=1,14
00111	C	RR(I) = ABS(I)
00113	C	CC(I) = COS(I)
00114	C	DO 100 K=1,14
00115	C	RI(I,K) = RS(I-K)
00120	C	100 CONTINUE
00121	C	
00121	C	INVERT R.
00121	C	
00121	C	

VRORAY.425772.1.100

```

00124 25* DO 350 K=1,NTERMS
00127 26* COM = R(I,K)
00130 27* THE TEST FOR EQUALITY BETWEEN NON-INTERMS MAY NOT BE MEANTINGFUL.
00133 28* IF (COM - FO,0.00) GO TO 400
00136 29* R(I,K) = 1.00
00139 30* DO 360 J=1,NTERMS
00142 31* R(I,J) = R(I,J)/COM
00145 32* CONTINUE
00148 33* DO 350 J=1,NTERMS
00151 34* IF (I.EQ,K) GO TO 350
00154 35* COM = R(I,K)
00157 36* R(I,K) = 0.00
00160 37* DO 370 J=1,NTERMS
00163 38* R(I,J) = R(I,J) - COM*(K,J)
00166 39* CONTINUE
00169 40* GO TO 500
00172 41* CONTINUE
00175 42* DO 400
00178 43* INVERSE FAILS.
00181 44* C
00184 45* CALL FAGAL(IPG, NAMEF)
00187 46* WRITE(6,*) K
00190 47* WRITE(6,*) COM
00193 48* CALL EXIT
00196 49* C
00199 50* CONTINUE
00202 51* DO 510 K=1,NTERMS
00205 52* COM(K) = 0.00
00208 53* DO 510 J=1,NTERMS
00211 54* CG(J) = COM(K) + R(K,J)*RR(I)
00214 55* C
00217 56* DO 520 J=1,14
00220 57* RR(I,J) = CG(J)
00223 58* DO 200 K=1,14
00226 59* RS(I,K) = R(I,K)
00229 60* CONTINUE
00232 61* RETURN
00235 62* C
00238 63* LOAD RESULTS INTO SINGLE PRECISION ARRAYS AND RETURN
00241 64* DO 200 I=1,14
00244 65* RR(I,J) = CG(J)
00247 66* CG(I) = COM(I)
00250 67* DO 200 K=1,14
00253 68* RS(I,K) = R(I,K)
00256 69* CONTINUE
00259 70* RETURN
00262 71* C
00265 72* END

```

\* CRASC REFERENCE BY SOURCE NUMBER \*

NAME:-----

```

BR : 0103 0105 0113 0203 0212
RRS : 0101 0104 0113 0212
CU : 0103 0105 0114 0177 0203 0213
COM : 0105 0127 0130 0136 0146 0153 0167
COS : 0101 0104 0114 0213
EXIT : 0172

```

VRORAY.425772.1.100

```

I : 0110 0113 0114 0120 0141 0144 0146 0147 0153 0200 0207 0212 0213 0217
IPG : 0163
J : 0133 0136 0150 0153
K : 0115 0120 0124 0127 0132 0136 0144 0146 0164 0174 0177 0203 0214 0217

```



VPC:AY,425772.1.100

LT FOR BUFFER BUFFER  
DATE, TIME, LEVEL OF OUTPUT ELEMENT: 15 JUN 73 09:24:58  
FORTRAN V: ISO VERSION 2.4

SURROUTINE BUFFER ENTRY POINT 000465

STORAGE USED (BLOCK, NAME, LENGTH)

0001 0005F 000507  
0002 0001A 013357  
0003 0001A 000000  
0004 0001A 007034

EXTERNAL REFERENCES (BLOCK, NAME)

0004 NTRN  
0005 EXIT  
0006 KEND  
0007 N1025  
0010 N0005  
0011 N0005

STORAGE ASSIGNED FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0000 010405 IF 0001 000044 IOL 0001 000421 IOL 0001 000104 1500  
0001 000120 1556 0001 010506 2F 0001 000051 201 0001 000251 2165  
0002 000204 2436 0001 000004 50L 0001 000015 000L 0001 000013 0014  
0003 000012 BULK 0001 000000 00L 0003 000024 DIL 0003 000240 0012  
0004 000274 002 0003 000324 00T 0003 000130 D01 0003 000120 0012  
0005 000110 002 0003 000324 00T 0003 000144 001 0003 000120 0012  
0006 000114 1002 0003 000324 00T 0003 000144 001 0003 000120 0012  
0007 000004 000F 0003 000003 000F 0003 000100 100 0003 000100 100  
0008 000477 000F 0003 000460 000 0003 000100 100 0003 000100 100  
0009 000374 000F 0003 000002 000F 0003 000100 100 0003 000100 100  
0010 000100 000F 0003 000014 100F 0003 000100 100 0003 000100 100

00100 10 C SURROUTINE BUFFER (NO, IFLAG)

00101 20 C  
00102 30 C  
00103 40 C  
00104 50 C  
00105 60 C  
00106 70 C  
00107 80 C  
00108 90 C  
00109 100 C  
00110 110 C  
00111 120 C  
00112 130 C  
00113 140 C  
00114 150 C  
00115 160 C

SURROUTINE BUFFERS BINARY TYPE INPUT.  
ASSUMES N001 OUTPUT SEQUENCE CN TAPE.  
DIMENSION RUL(100), IRI(100), DR(200), N(14)  
DIL(100), DRI(100), DR2(100), F12(100), F0CT(100),  
E11(100), F22(100), F33(100), F12(100), F0CT(100),  
IPIV(100), IPIV2(100), IPIV3(100), MATI(5),  
N006(100), N006F(100), RATE(100), STRESS(100),  
STREU(100), T(100), TEMP(100),  
DOUBLE PRECISION DR, IPIV1, IPIV2, IPIV3, E0CT, N006, N006F  
COMMON /INPUT/ ITEST, N0P, PRES, KTEMP, K0RE, MATIN, RULK, REYA,  
TEMP, RATE, DT, STRESS, DIL, T, E11, F22, E03, F12,

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```

00106 17* 2 STRUE, C*1, C*2, DR*2, INV1, INV2, INV3, NORMF,
00106 18* 3 NORM, FOC
00106 19* C EQUIVALENT ( R(1), IR(1) )
00107 20* C
00107 21* C DATA HEND/END//
00110 22* C
00118 23* C IF (FLAG.FQ.1) GO TO 10
00118 24* C CONTINUE
00118 25* 50 HEAD(5,1) MTEST
00118 26* IF (MTEST.FQ.NFND) GO TO 200
00120 27* C
00120 28* C CALL NTRAN(NU,4,MTEST,1400.0,1.0)
00120 29* C CALL NTRAN(NU,2,2200.0,R(1,D))
00122 30* C
00123 31* C IF (FLAG.FQ.1) RETURN
00123 32* C 1-(LD+1) 999.10.20
00123 33* C 20 CONTINUE
00124 34* C
00126 35* 10 LOAD SINGLE PRECISION/INTEGER ARRAYS.
00131 36* 20
00131 37* C
00131 38* C
00131 39* C MTEST = T(1)
00132 40* RMP = IR(2)
00133 41* PREFS = R(3)
00134 42* KTRMP = IR(4)
00135 43* KONE = IR(5)
00136 44* DO 21 K=1,5
00137 45* J = K*5
00142 46* MATIN(K) = IR(J)
00143 47* 21
00145 48* RULK = R(11)
00146 49* RFTA = R(12)
00146 50* C
00147 51* DO 22 I=1,14
00147 52* 22 N(I) = 12 + (I-1)*RMP
00152 53* C
00154 54* DO 100 I=1,RMP
00157 55* J = N(1)
00157 56* T(RP(I)) = R(J*I)
00161 57* J = N(2)
00162 58* RATE(I) = R(J*I)
00163 59* J = N(3)
00164 60* DT(I) = R(J*I)
00165 61* J = N(4)
00166 62* STRESS(I) = R(J*I)
00167 63* J = N(5)
00170 64* DT(I) = R(J*I)
00171 65* J = N(6)
00172 66* T(I) = R(J*I)
00173 67* J = N(7)
00174 68* E1(I) = R(J*I)
00175 69* J = N(8)
00176 70* E2(I) = R(J*I)
00177 71* J = N(9)
00200 72* E3(I) = R(J*I)
00201 73* J = N(10)
00202 74* E12(I) = R(J*I)
00203 75* J = N(11)
00204 76* STRUE(I) = R(J*I)

```

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```

00205 77* J = N(12) = R(J+1)
00206 78* D4(1) = R(J+1)
00207 79* J = N(13)
00210 80* D4(1) = R(J+1)
00211 81* J = N(14)
00212 82* D4(1) = R(J+1)
00213 83* CONTINUE
00214 84* C
00215 85* C LOAD DOUBLE PRECISION ARRAYS.
00216 86* C
00217 87*
00220 88* 23 10 23 1=1,11
00221 89* 23 H(1) = (1-1)*DP
00222 90*
00223 91* D4 110 1=1,N,P
00224 92* J = N(1)
00225 93* I=J(1) = DP(J+1)
00226 94* J = N(2)
00227 95* I=J(1) = DP(J+1)
00228 96* J = N(3)
00229 97* I=J(1) = DP(J+1)
00230 98* J = N(4)
00231 99* I=J(1) = DP(J+1)
00232 100* J = N(5)
00233 101* I=J(1) = DP(J+1)
00234 102* J = N(6)
00235 103* I=J(1) = DP(J+1)
00236 104* J = N(7)
00237 105* I=J(1) = DP(J+1)
00238 106* J = N(8)
00239 107* I=J(1) = DP(J+1)
00240 108* J = N(9)
00241 109* I=J(1) = DP(J+1)
00242 110* J = N(10)
00243 111* I=J(1) = DP(J+1)
00244 112* J = N(11)
00245 113* I=J(1) = DP(J+1)
00246 114* J = N(12)
00247 115* I=J(1) = DP(J+1)
00248 116* J = N(13)
00249 117* I=J(1) = DP(J+1)
00250 118* J = N(14)
00251 119* I=J(1) = DP(J+1)
00252 120* J = N(15)
00253 121* I=J(1) = DP(J+1)
00254 122* J = N(16)
00255 123* I=J(1) = DP(J+1)
00256 124* J = N(17)
00257 125* I=J(1) = DP(J+1)
00258 126* J = N(18)
00259 127* I=J(1) = DP(J+1)
00260 128* J = N(19)
00261 129* I=J(1) = DP(J+1)
00262 130* J = N(20)
00263 131* I=J(1) = DP(J+1)
00264 132* J = N(21)
00265 133* I=J(1) = DP(J+1)
00266 134* J = N(22)
00267 135* I=J(1) = DP(J+1)
00268 136* J = N(23)
00269 137* I=J(1) = DP(J+1)
00270 138* J = N(24)
00271 139* I=J(1) = DP(J+1)
00272 140* J = N(25)
00273 141* I=J(1) = DP(J+1)
00274 142* J = N(26)
00275 143* I=J(1) = DP(J+1)
00276 144* J = N(27)
00277 145* I=J(1) = DP(J+1)
00278 146* J = N(28)
00279 147* I=J(1) = DP(J+1)
00280 148* J = N(29)
00281 149* I=J(1) = DP(J+1)
00282 150* J = N(30)
00283 151* I=J(1) = DP(J+1)
00284 152* J = N(31)
00285 153* I=J(1) = DP(J+1)
00286 154* J = N(32)
00287 155* I=J(1) = DP(J+1)
00288 156* J = N(33)
00289 157* I=J(1) = DP(J+1)
00290 158* J = N(34)
00291 159* I=J(1) = DP(J+1)
00292 160* J = N(35)
00293 161* I=J(1) = DP(J+1)
00294 162* J = N(36)
00295 163* I=J(1) = DP(J+1)
00296 164* J = N(37)
00297 165* I=J(1) = DP(J+1)
00298 166* J = N(38)
00299 167* I=J(1) = DP(J+1)
00300 168* J = N(39)
00301 169* I=J(1) = DP(J+1)
00302 170* J = N(40)
00303 171* I=J(1) = DP(J+1)
00304 172* J = N(41)
00305 173* I=J(1) = DP(J+1)
00306 174* J = N(42)
00307 175* I=J(1) = DP(J+1)
00308 176* J = N(43)
00309 177* I=J(1) = DP(J+1)
00310 178* J = N(44)
00311 179* I=J(1) = DP(J+1)
00312 180* J = N(45)
00313 181* I=J(1) = DP(J+1)
00314 182* J = N(46)
00315 183* I=J(1) = DP(J+1)
00316 184* J = N(47)
00317 185* I=J(1) = DP(J+1)
00318 186* J = N(48)
00319 187* I=J(1) = DP(J+1)
00320 188* J = N(49)
00321 189* I=J(1) = DP(J+1)
00322 190* J = N(50)
00323 191* I=J(1) = DP(J+1)
00324 192* J = N(51)
00325 193* I=J(1) = DP(J+1)
00326 194* J = N(52)
00327 195* I=J(1) = DP(J+1)
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WDC:AY.425772.1.1r.0

SINGLE WOUND HOLLERITH STRINGS-----  
C10 : 0110

[illegible]

**LABELS---**

1:	0115	0272
2:	0265	0273

Ms. A. 9. 2. 1. 5772. 1. 1. 176

01 FOR POST,POST  
 02 DATE, TIME, LEVEL OF OUTPUT ELEMENT: 15 JUN 73 09:20 (NO)  
 03 CONTRAN V: ISN VERSION 2.0

MAIN PROGRAM

STORAGE USED (BLOCK, NAME, LENGTH)

0001	*CODE	000235
0000	*DATA	000160
0002	*BLANK	000000
0003	INPUT	007034

### EXTERNAL REFERENCES (BLOCK, NAME)

0004	RUFFER
0005	PGPOST
0006	EXIT
0007	NPF\$S
0010	NWNU\$
0011	N102\$
0012	NS10P\$

[illegible]

0001	000115	130L	0001	000042	1256	0001	000147	1566	0001	000021	200L	0000	000020	2F
0002	000070	4F	0001	000086	50L	0000	000101	6F	0000	000145	7F	0003	000001	8F1A
0003	000012	4ULK	0003	000634	01L	0000	000210	0R1	0003	000240	0012	0003	000276	4F2
0004	000034	0T	0003	000659	EOCT	0003	000134	EL1	0003	000260	EL3	0003	000310	EL2
0005	000154	F33	0000	000016	1	0000	000003	IFLAG	0003	000260	IN01	0003	000310	1V02
0006	000344	1V3	0000	000634	1V3	0000	000000	1F0P	0003	000000	1F0T	0003	000000	1F0P
0007	000344	1V3	0000	000634	1V3	0000	000000	1F0P	0003	000000	1F0T	0003	000000	1F0P
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0010	000344	1V3	0000	000634	1V3	0000	000000	1F0P	0003	000000	1F0T	0003	000000	1F0P
0011	000344	1V3	0000	000634	1V3	0000	000000	1F0P	0003	000000	1F0T	0003	000000	1F0P
0012	000344	1V3	0000	000634	1V3	0000	000000	1F0P	0003	000000	1F0T	0003	000000	1F0P
0013	000344	1V3	0000	000634	1V3	0000	000000	1F0P	0003	000000	1F0T	0003	000000	1F0P
0014	000344	1V3	0000	000634	1V3	0000	000000	1F0P	0003	000000	1F0T	0003	000000	1F0P
0015	000344	1V3	0000	000634	1V3	0000	000000	1F0P	0003	000000	1F0T	0003	000000	1F0P
0016	000344	1V3	0000	000634	1V3	0000	000000	1F0P	0003	000000	1F0T	0003	000000	1F0P
0017	000344	1V3	0000	000634	1V3	0000	000000	1F0P	0003	000000	1F0T	0003	000000	1F0P
0018	000344	1V3	0000	000634	1V3	0000	000000	1F0P	0003	000000	1F0T	0003	000000	1F0P
0019	000344	1V3	0000	000634	1V3	0000	000000	1F0P	0003	000000	1F0T	0003	000000	1F0P
0020	000344	1V3	0000	000634	1V3	0000	000000	1F0P	0003	000000	1F0T	0003	000000	1F0P
0021	000344	1V3	0000	000634	1V3	0000	000000	1F0P	0003	000000	1F0T	0003	000000	1F0P
0022	000344	1V3	0000	000634	1V3	0000	000000	1F0P	0003	000000	1F0T	0003	000000	1F0P
0023	000344	1V3	0000	000634	1V3	0000	000000	1F0P	0003	000000	1F0T	0003	000000	1F0P
0024	000344	1V3	0000	000634	1V3	0000	000000	1F0P	0003	000000	1F0T	0003	000000	1F0P
0025	000344	1V3	0000	000634	1V3	0000	000000	1F0P	0003	000000	1F0T	0003	000000	1F0P
0026	000344	1V3	0000	000634	1V3	0000	000000	1F0P	0003	000000	1F0T	0003	000000	1F0P
0027	000344	1V3	0000	000634	1V3	0000	000000	1F0P	0003	000000	1F0T	0003	000000	1F0P
0028	000344	1V3	0000	000634	1V3	0000	000000	1F0P	0003	000000	1F0T			

00100	14	C	POST-PROCESSOR FOR ML001.
00100	14	C	

	4*	5*	C	
000100				DIVISION
000101	1			DIL(100), DR1(100), DR2(100), DR12(100), DT,1001,
000102	2			E11(100), E22(100), F33(100), E12(100), FOC(100),
000103	3			INVI(100), INV2(100), INV3(100), MATIO(5),
000104	4			NORM16(100), NORMF(100), RATE(100), STRESS(100),
000105	5*			STRUL(100), T(100), TEMP(100), ITEMP(2), ITYPE(3)
000106			C	
000107	10*			DOUBLE PRECISION INV1, INV2, INV3, EOC1, NORM, NORMF, ITEMP, ITYPE
000108	11*			
000109	12*		C	
000110				COMMON /INPUT/ TEST, NDP, PRES, KTEMP, CODE, MATIO, BULK, RETA,
000111	13*			TEMP, RATE, DT, STRESS, NIL, T, E11, F22, E23, E12,
000112	14*			STRIUE, PRI, DR2, DR12, INV1, INV2, INV3, NORMF,
000113	15*			NORM, FOC1
000114	16*			



VOLUME 772,1,100

00207 700 3 T114,STEADY, //)  
 00210 790 7 F10MAT(11, T10,14, T20,F10.3, T17,3F15.4, T02,F10.4, T112,F10.4 )  
 00211 800 F10

\* CROSS REFERENCE BY SOURCE NUMBER \*

MOLLEWITH STRINGS &gt; 1 WORD-----

CO-STANT : 3105  
 VARIABLE : 0105  
 UNIAIAL : 0105  
 RIAXIAL : 0105

SINGLE WORD MOLLEWITH STRINGS-----

SHEAR : 0105

NAMES-----

BETA : 0104 0121 0145 0152 0175

BULK : 0104 0121 0145 0152 0175

DIL : 0101 0104 0161

L1 : 0101 0104

F12 : 0101 0104

L2 : 0101 0104

L1 : 0101 0104

F12 : 0101 0104

L2 : 0101 0104

L1 : 0101 0104

F12 : 0101 0104

L2 : 0101 0104

L1 : 0101 0104

F12 : 0101 0104

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F12 : 0101 0104

L2 : 0101 0104

L1 : 0101 0104

F12 : 0101 0104

L2 : 0101 0104

APPENDIX G

COMPUTERIZED CHARACTERIZATION PROCEDURES FOR LINEAR  
VISCOELASTIC MATERIALS USING ARBITRARY DEFORMATION HISTORIES

By  
Richard J. Farris

G-1

## 1.0 INTRODUCTION

The purpose of this appendix is to provide an improved means of linear viscoelastic characterization. The computer code presented in this appendix was the first code developed on this contract and formed the basis for the nonlinear characterization codes. The code calculates the best fit distortional stress-strain relation for mixed uniaxial, biaxial and shear tests having complex deformation histories including transient temperature histories. The representation used is

$$\sigma^{(D)}(t) = \int_0^t G(t'-\xi') \dot{\epsilon}^{(D)}(\xi) d\xi \quad (1)$$

where  $\sigma^{(D)}$  = distortional stress

$\epsilon^{(D)}$  = distortional strain

Thermal effects are included in that the distortional strain depends upon thermal dilatation and the reduced time,  $t'-\xi'$ , depends upon temperature in the usual manner

$$t'-\xi' = \int_{\xi}^t d\tau / A_T(\tau) \quad (2)$$

The kernel function  $G(t)$  can be represented as either a Prony series or as a power law series depending upon users preference.

In the Prony series representation the kernel function becomes

$$G(t) = A_1 + \sum_{i=2}^M A_i e^{-\beta_i t} \quad (3)$$

and in the power law representation the kernel function is

$$G(t) = A_1 + \sum_{i=2}^M A_2 (1 + \beta_i t)^{N_i} \quad (4)$$

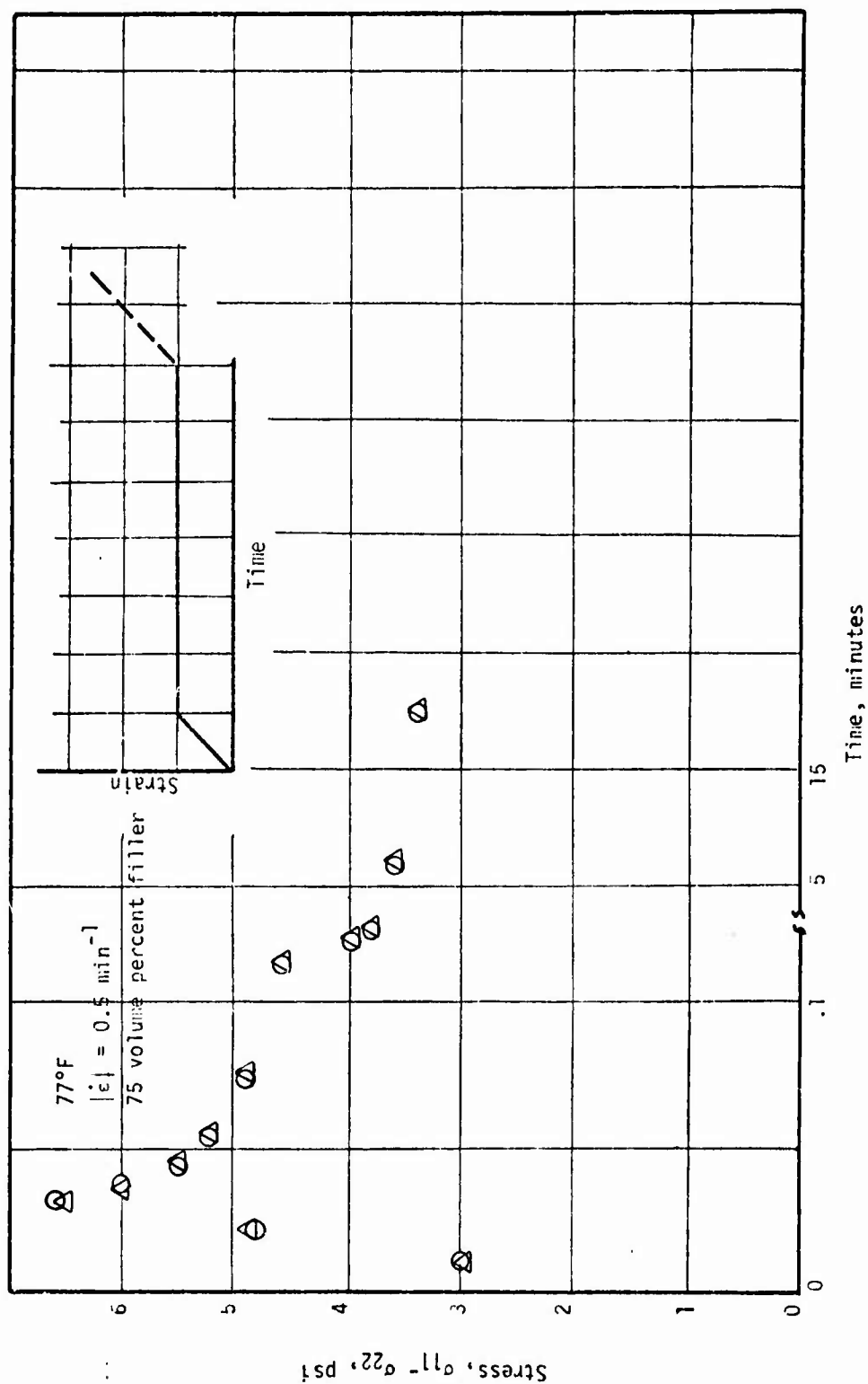
The code requires as input parameters the time-temperature shift function and a family of exponents  $\beta_i$ ,  $i < 15$ , for the Prony series representation. The code then computes the best fit linear coefficients  $A_i$  based on a relative regression analysis as discussed in the text of this report. Once having determined the coefficients the program can be used to calculate the response to any history of interest.

There are many advantages to this type of characterization method some of which are given below.

- All of the data obtained on a material can be used in the characterization.
- The method can provide the best approximation to any complex history.
- Provides the best fit to all of the data not just a relaxation test.
- Provides direct comparisons between observed and predicted data.
- The method is much more accurate than usual methods and provides statistical information regarding accuracy and variability.
- Eliminates the need for special tests and test equipment, such as stress-relaxometers, since characterization can be carried out from any experiment.
- It provides a practical method for linear and nonlinear viscoelastic characterization.

As an example of the application of the method the following figures are included. Figure 1 demonstrates the excellent results obtained when a five term Prony series is fit to a ramp loaded stress-relaxation experiment for a composite propellant. From this experiment, one might get the misleading impression that linear viscoelasticity was a good approximation to propellant response. Figure 2 shows the linear viscoelastic analytical continuation (based on the fit from Figure 1) compared to the experimental results when straining is again commenced. Obviously the material is not linearly viscoelastic. The remaining figures illustrate the excellent fit obtained in Solethane 113, an unfilled rubber, on a series of experiments using complex histories at temperatures from  $-65^{\circ}\text{F}$  to  $+150^{\circ}\text{F}$ . The last figure shows a comparison of predicted transient thermoviscoelastic stress response for Solethane 113 with experimental results. The Solethane characterization was carried out using 15 Prony series terms and the predictions were within  $\pm 10\%$  for one standard deviation demonstrating that linear viscoelasticity is an excellent approximation to the behavior of this unfilled polymer.

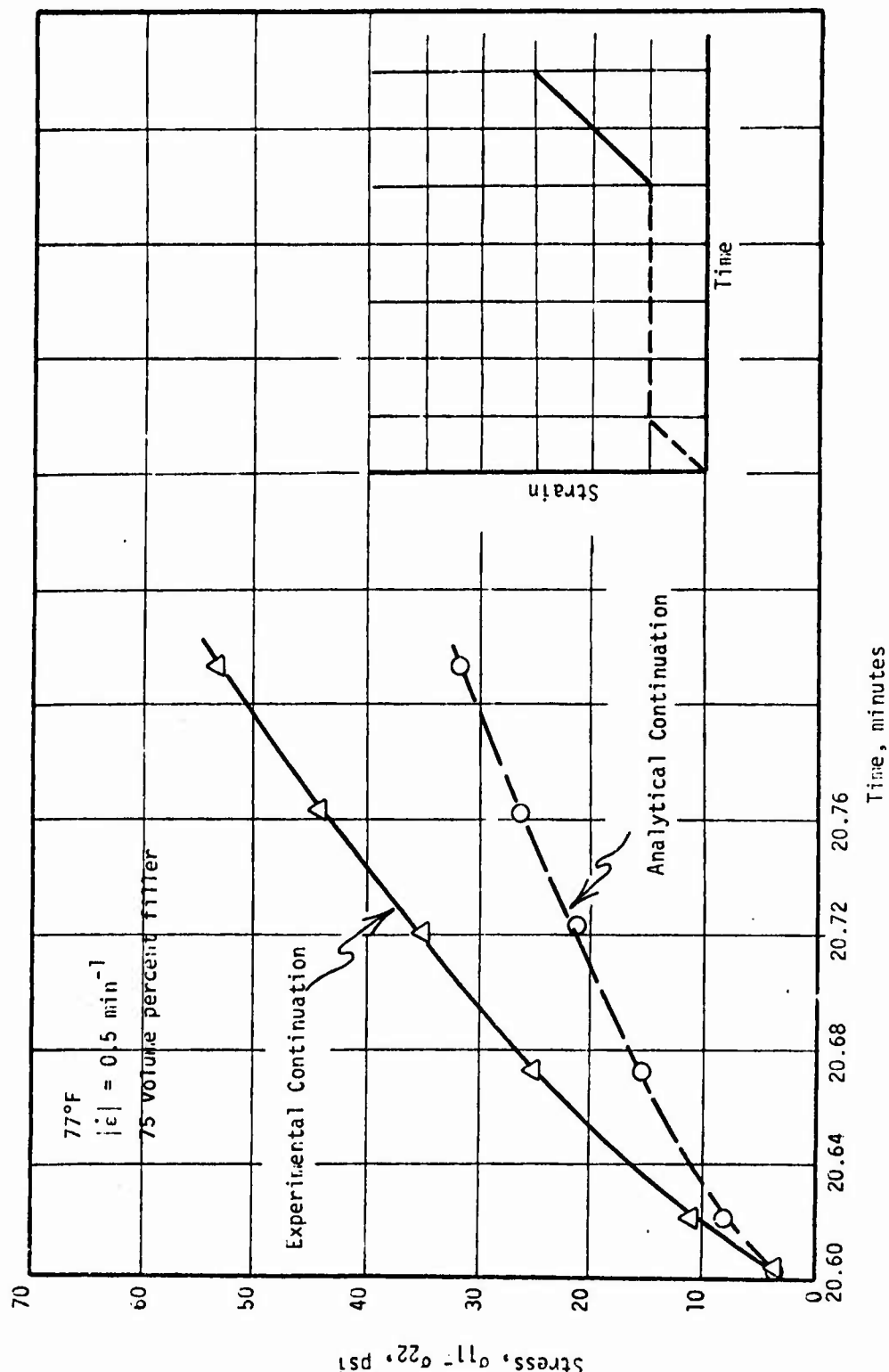
COMPARISON OF LINEAR VISCOELASTIC PREDICTION AND FIRST  
STRESS-RELAXATION FOR A COMPOSITE SOLID PROPELLANT



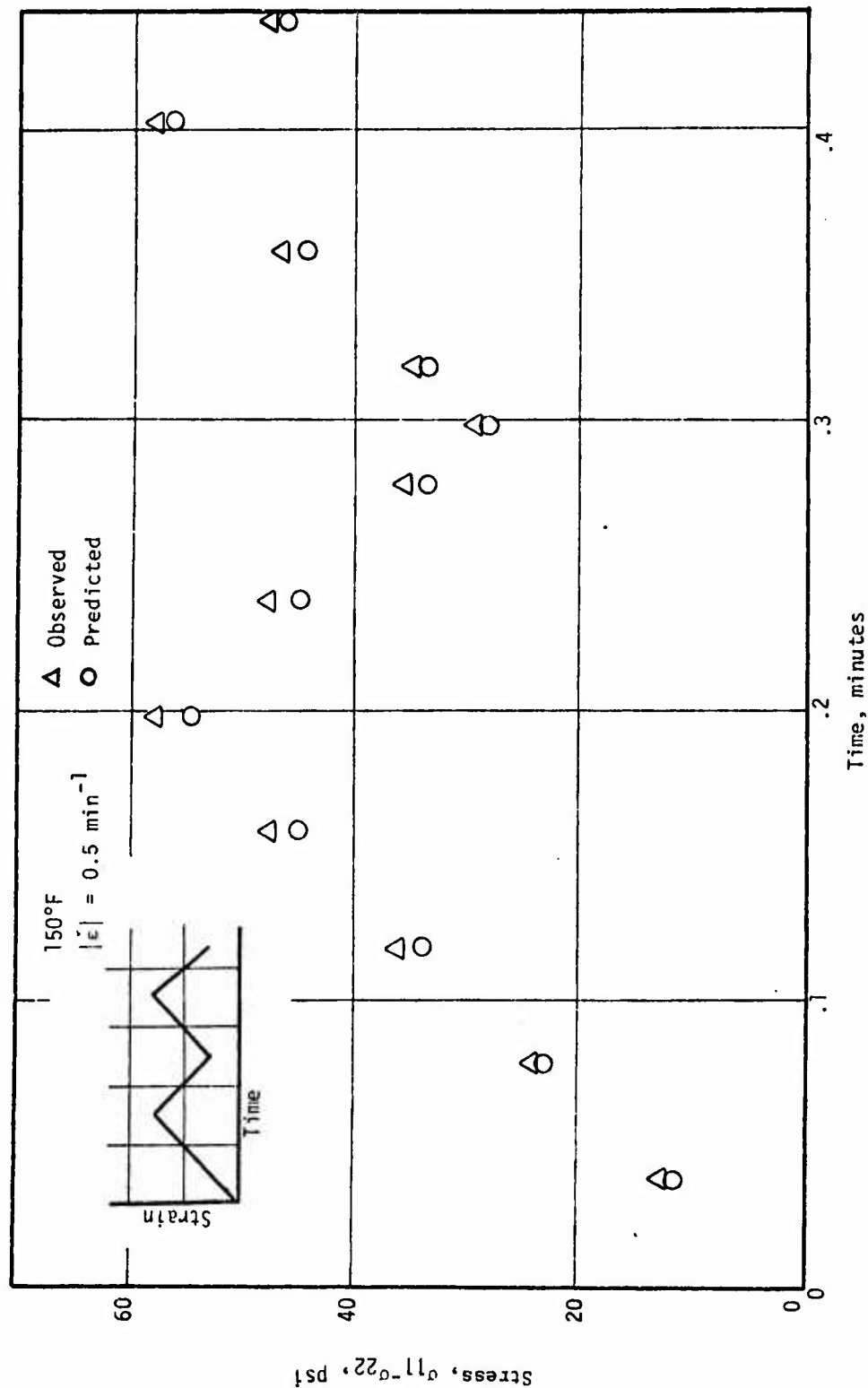
G-3

Figure 1

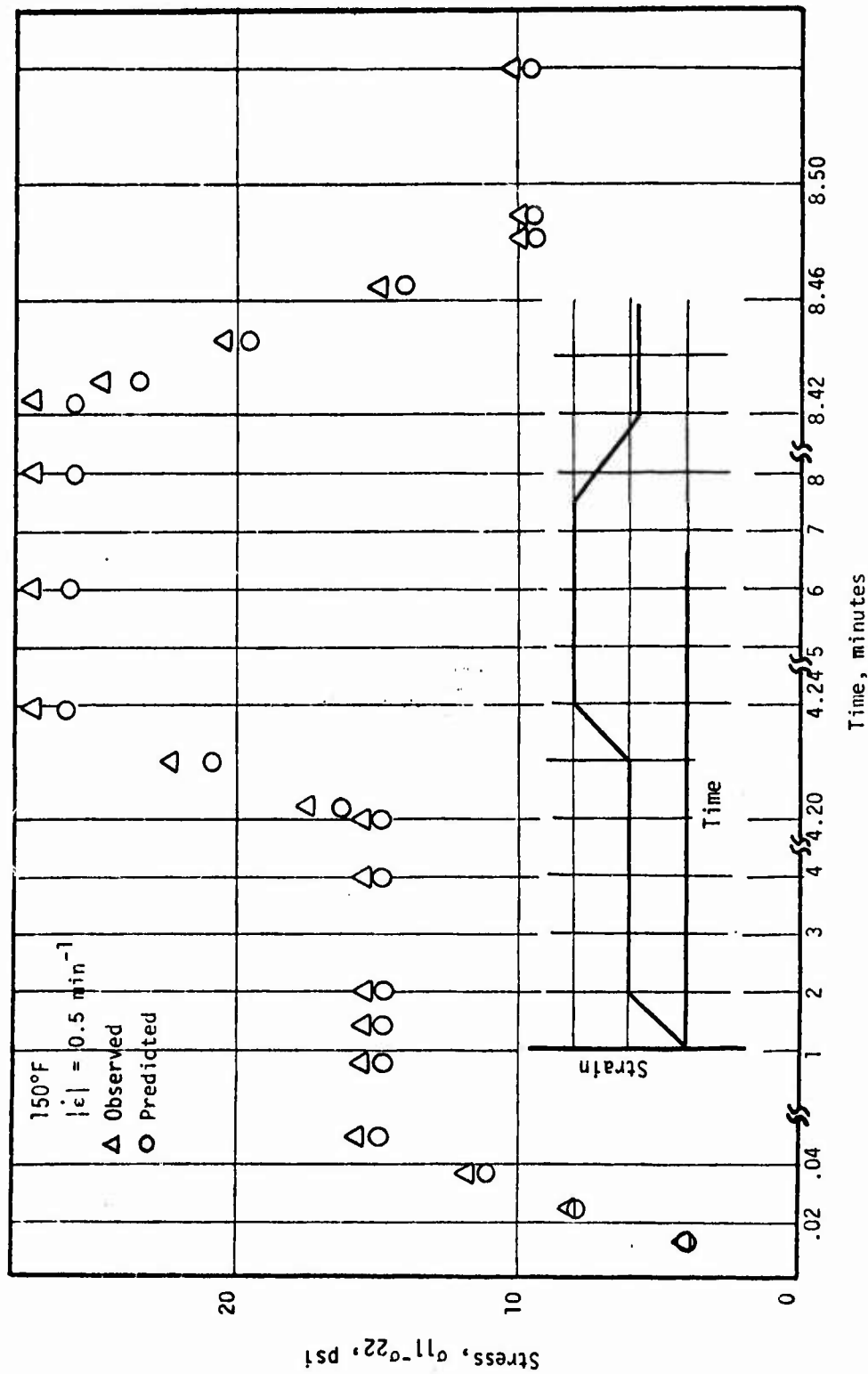
COMPARISON OF EXPERIMENTAL AND ANALYTICAL EXTENSIONS USING CHARACTERIZATION  
FROM FIRST RELAXATION FOR THE COMPOSITE SOLID PROPELLANT



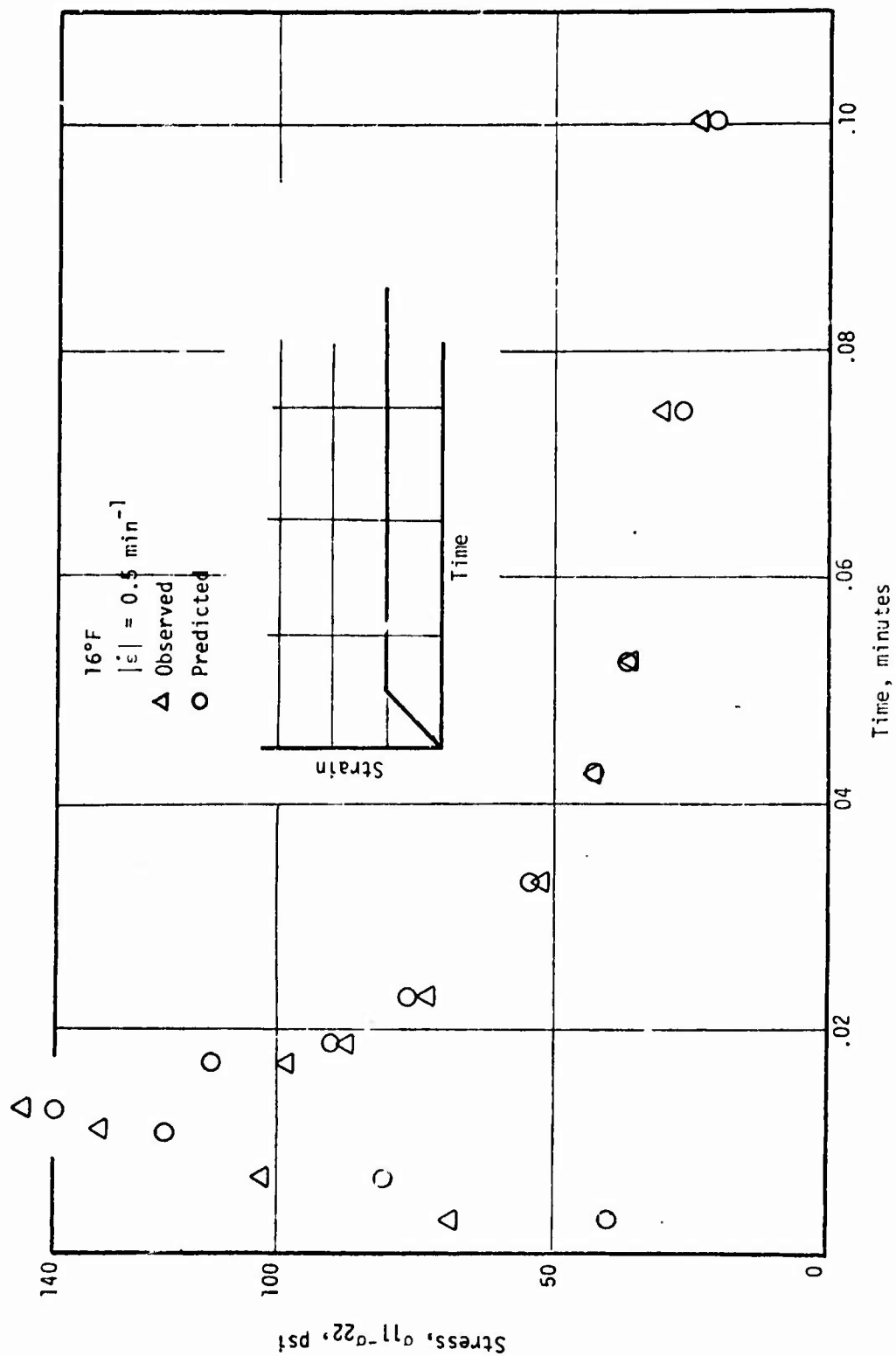
COMPARISON OF LINEAR VISCOELASTIC PREDICTIONS  
AND EXPERIMENTAL DATA FOR SOLITHANE 113



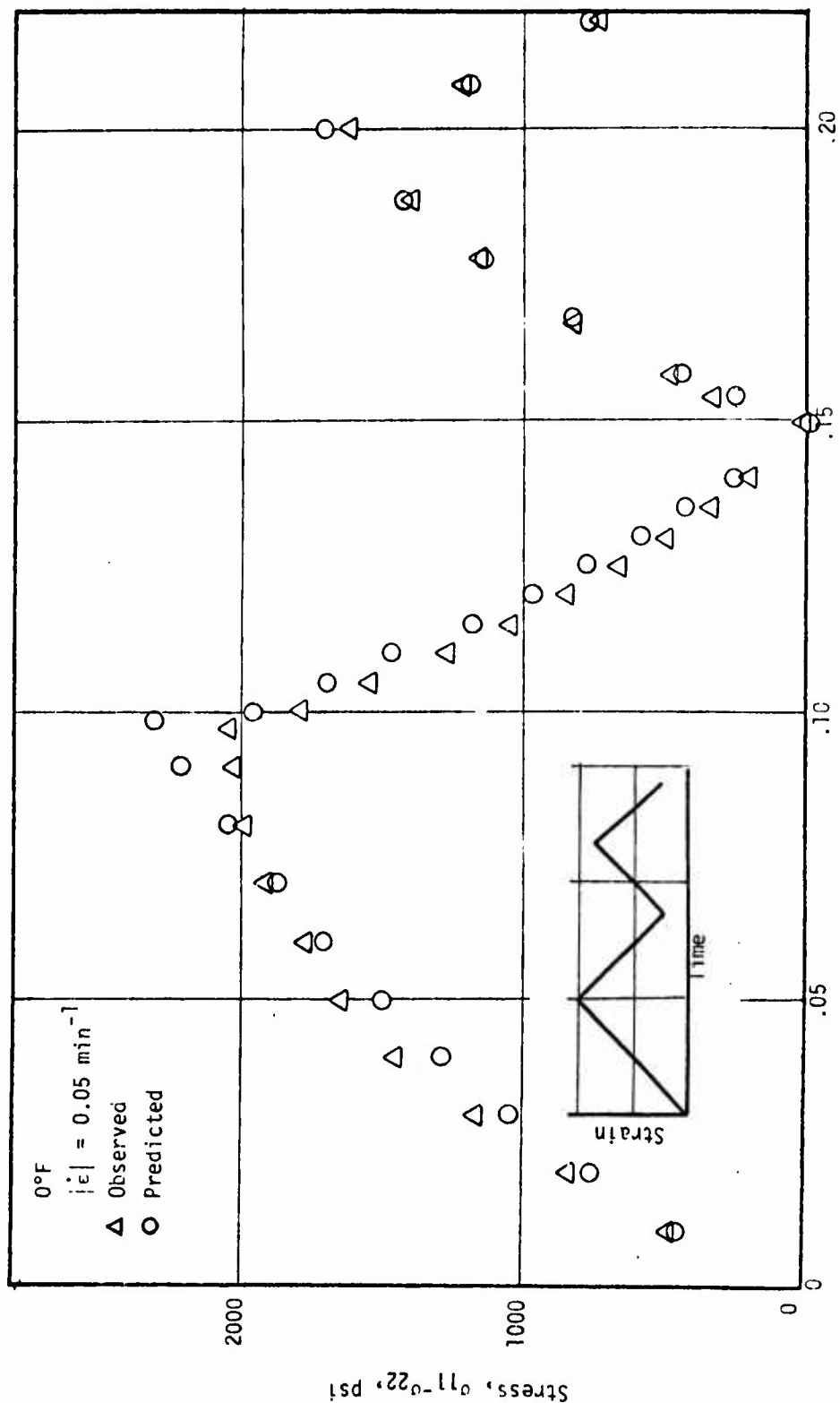
COMPARISON OF LINEAR VISCOELASTIC PREDICTIONS  
AND EXPERIMENTAL DATA FOR SOLITHANE 113



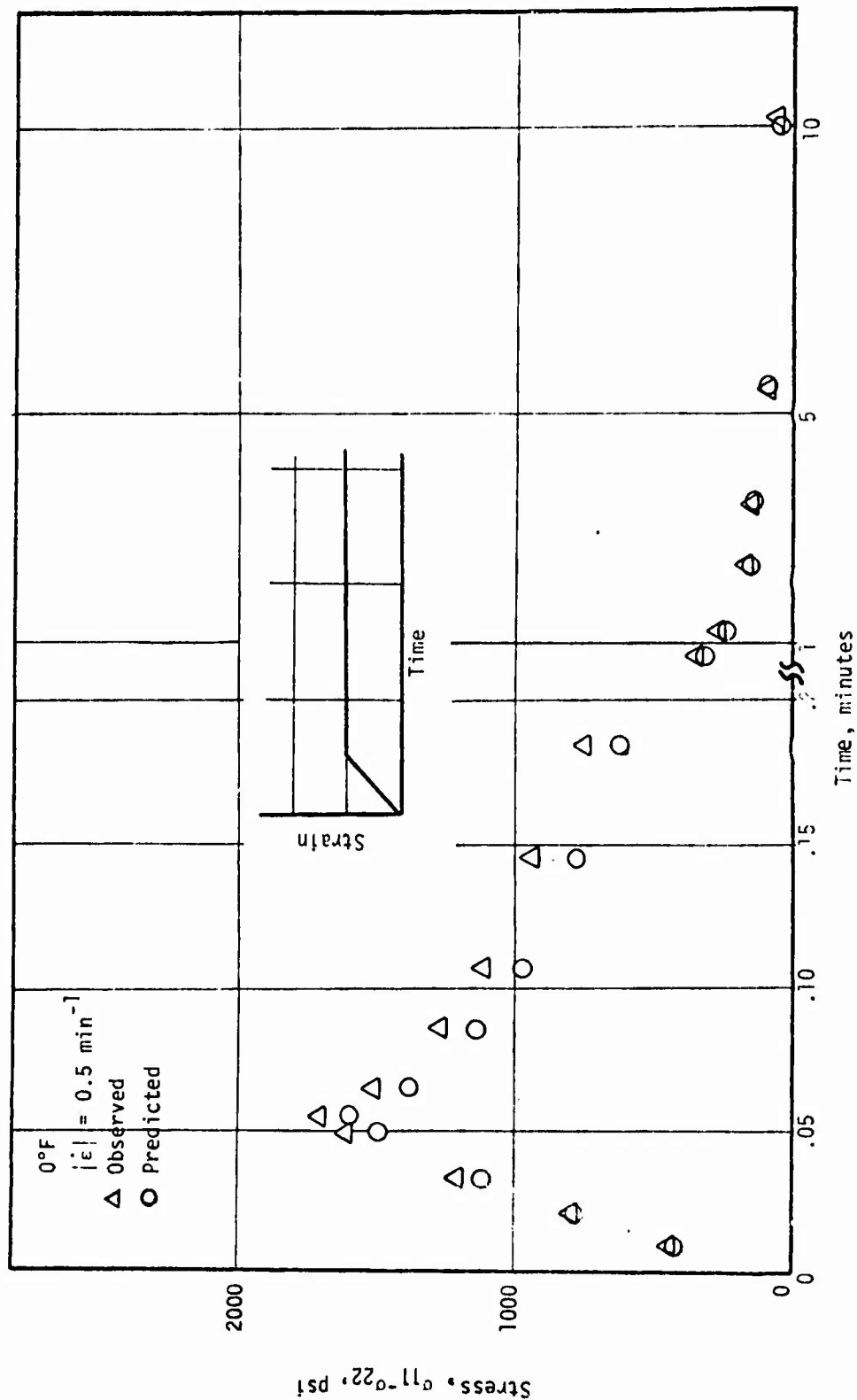
COMPARISON OF LINEAR VISCOELASTIC PREDICTIONS  
AND EXPERIMENTAL DATA FOR SOLITHANE 113



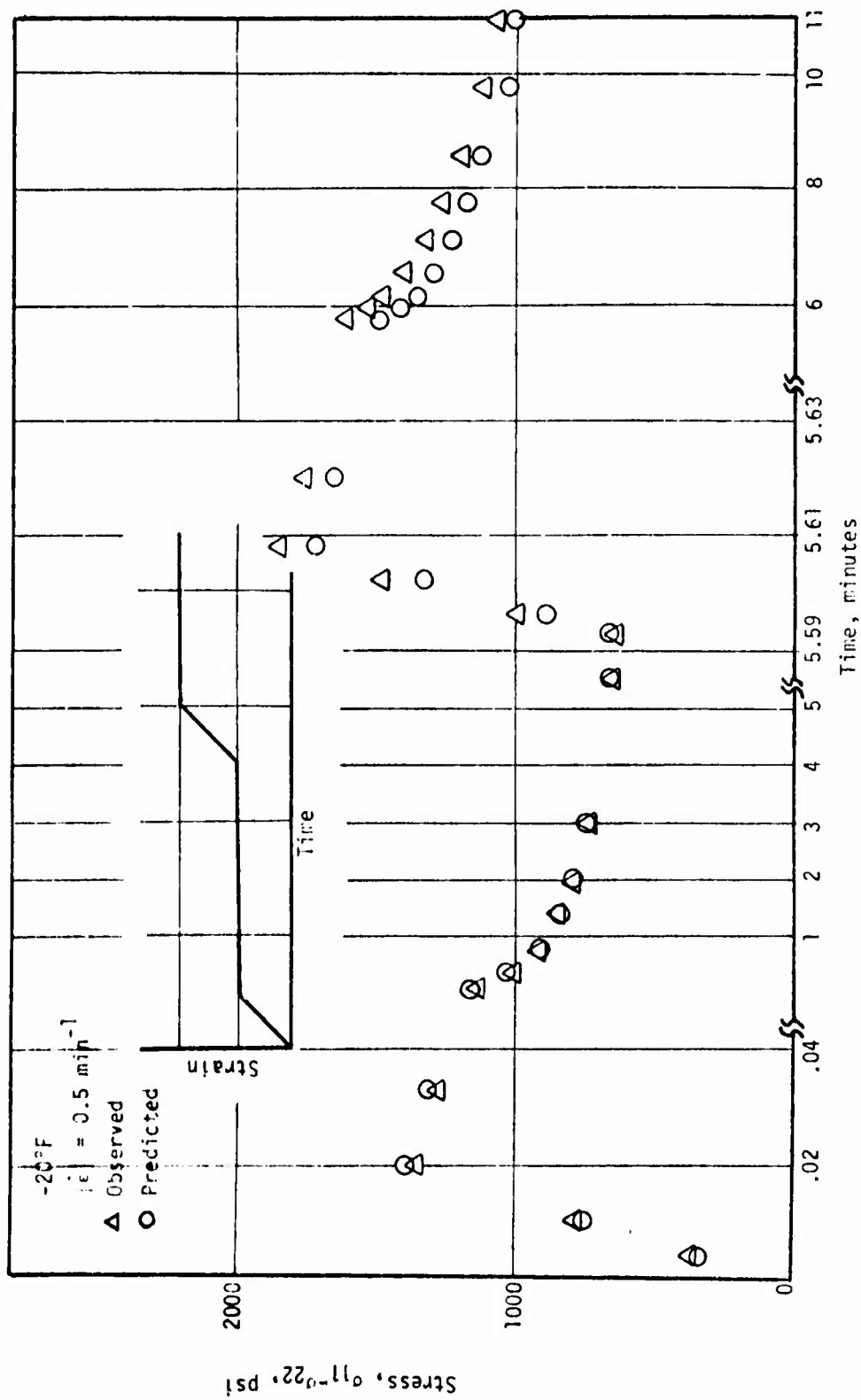
COMPARISON OF LINEAR VISCOELASTIC PREDICTIONS  
AND EXPERIMENTAL DATA FOR SOLITHANE 113



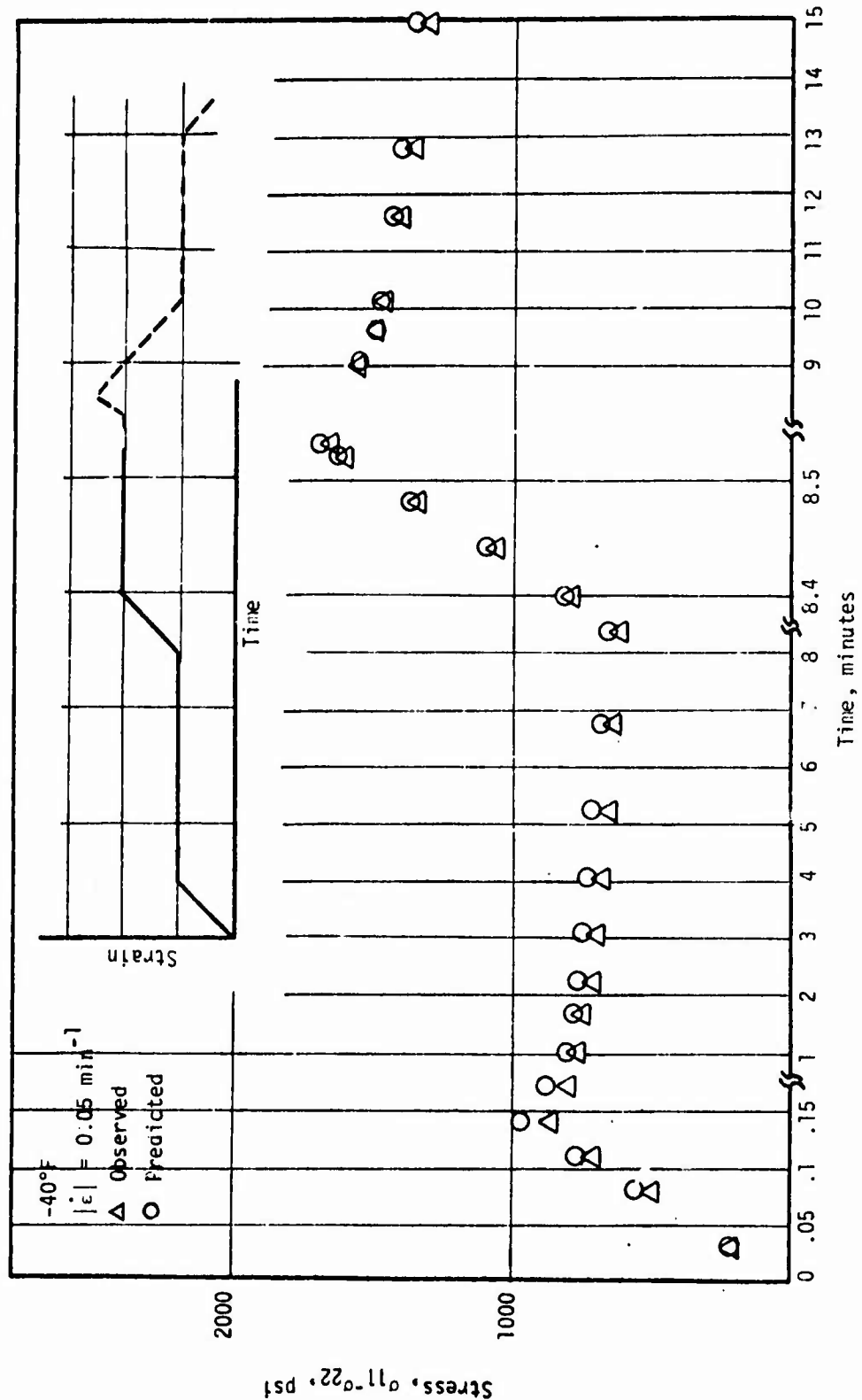
COMPARISON OF LINEAR VISCOELASTIC PREDICTIONS  
AND EXPERIMENTAL DATA FOR SOLITHANE 113



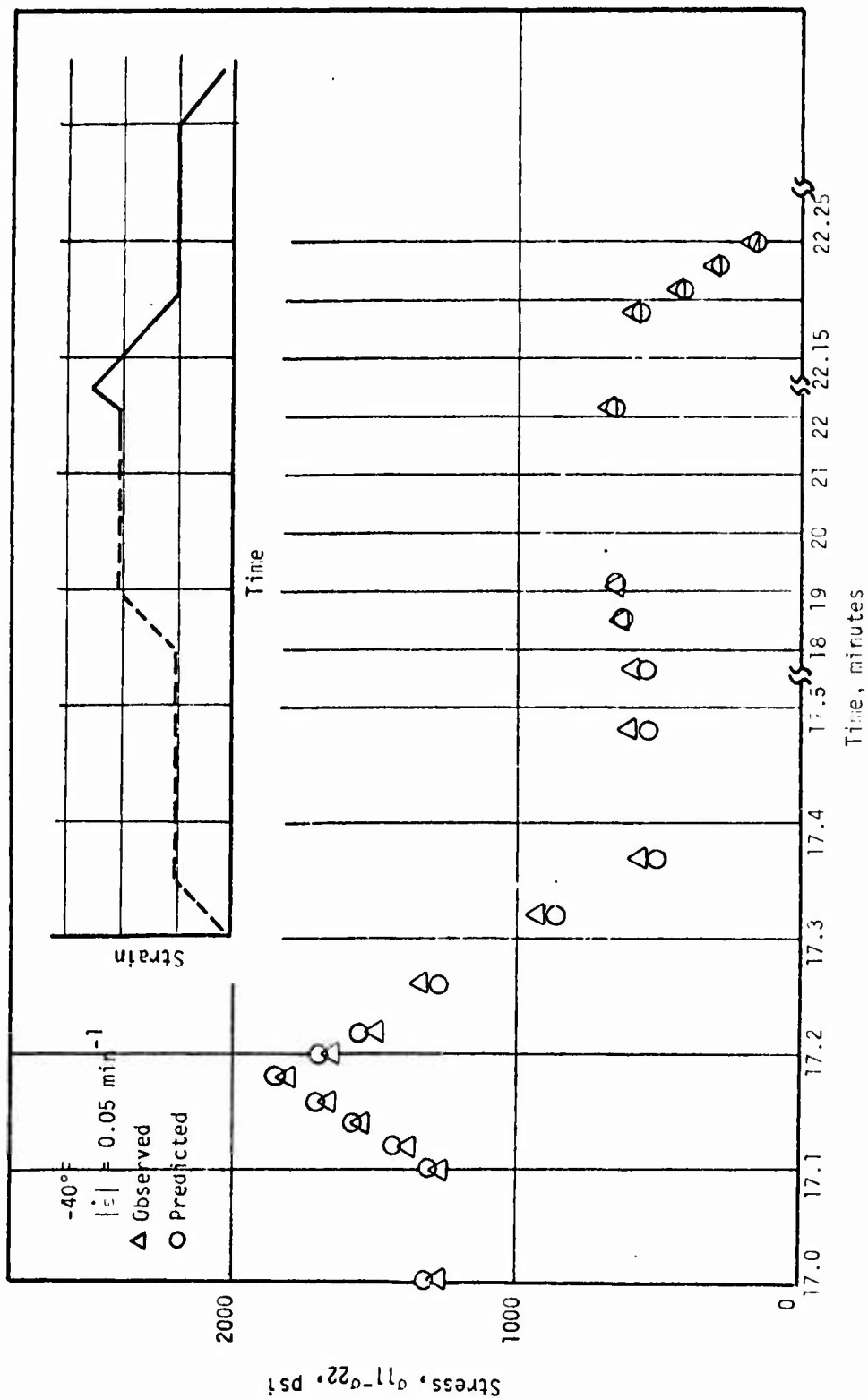
COMPARISON OF LINEAR VISCOELASTIC PREDICTIONS  
AND EXPERIMENTAL DATA FOR SOLITHANE 113



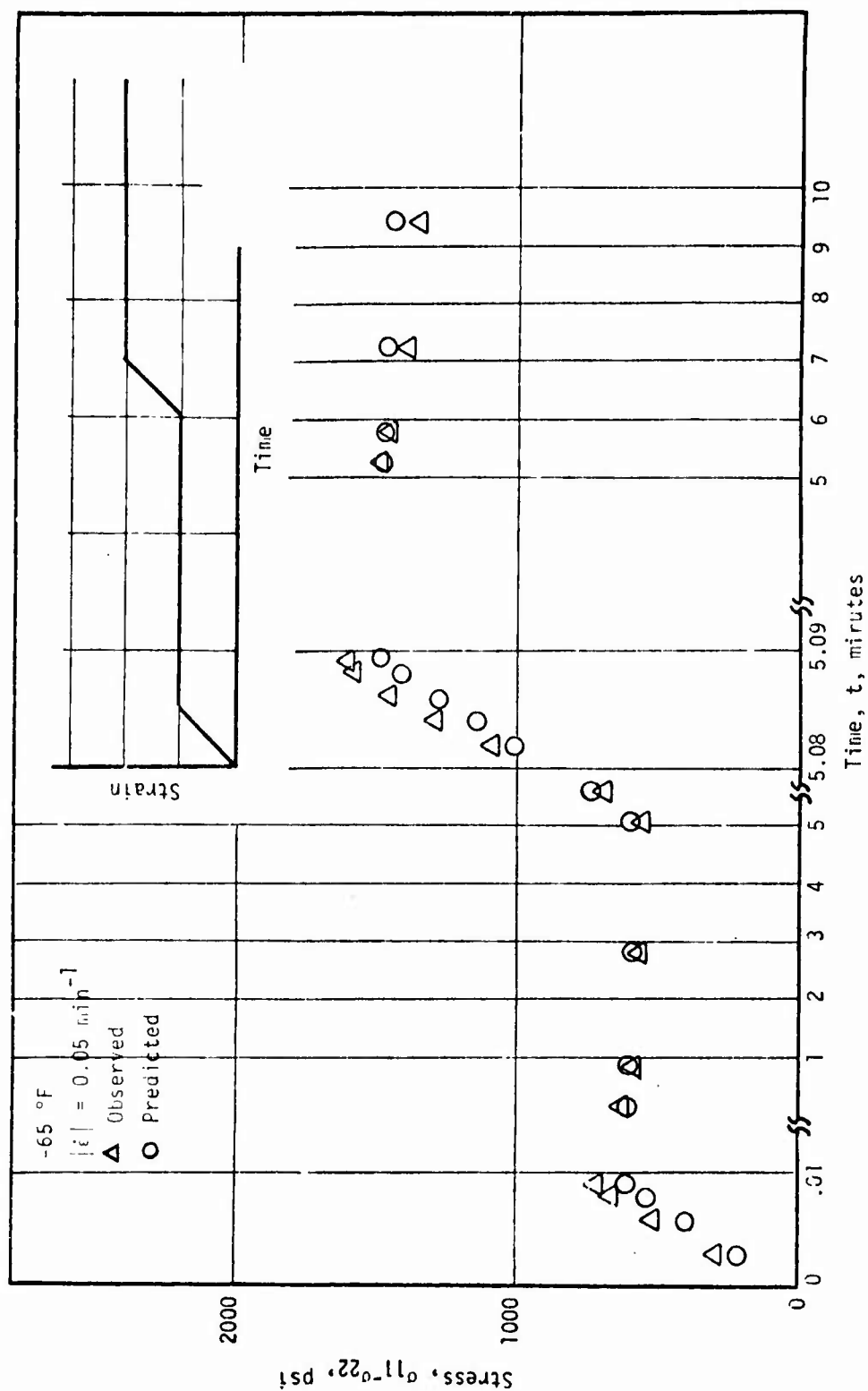
COMPARISON OF LINEAR VISCOELASTIC PREDICTIONS  
AND EXPERIMENTAL DATA FOR SOLITHANE 113



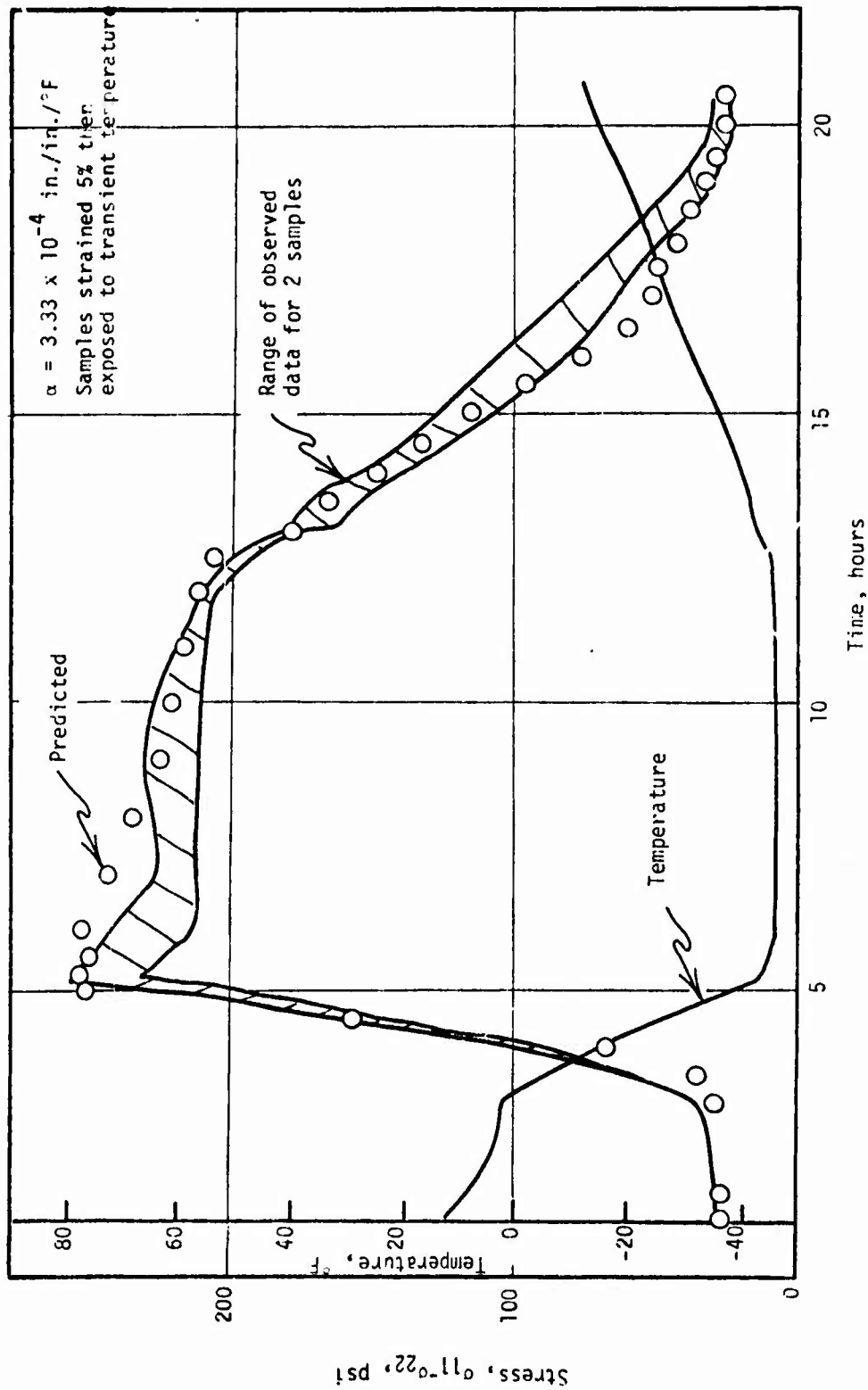
COMPARISON OF LINEAR VISCOELASTIC PREDICTIONS  
AND EXPERIMENTAL DATA FOR SOLITHANE 113



# COMPARISON OF LINEAR VISCOELASTIC PREDICTIONS AND EXPERIMENTAL DATA FOR SOLITHANE 113



COMPARISON OF LINEAR VISCOELASTIC PREDICTIONS AND EXPERIMENTAL DATA  
FOR THERMOVISCOELASTIC EXPERIMENT ON SOLITHANE 113



## 2.0 PROGRAM INSTRUCTIONS

This section presents a description of the basic variables of the LINVIS linear viscoelastic characterization code. It includes a data sheet showing the input variables and formats, a sample problem and a listing of the program.

### 2.1 BASIC VARIABLES

AT	Vector of shift function - input
AVGAT	Average value of AT - calculated
B	Constant in the power series term $(1 + Bt)^{NN}$ or the exponent in the prony series term $e^{-Bt}$ - input
BB	Column vector in regression equation
BETA	Volumetric expansion coefficient - input
CO	Regression coefficients - calculated
D	Slope of shift function - calculated
DEV	Percent error between calculated and observed stress
DEVRAT	Deviation strain rate - calculated
DT	Time increment - input
E1, E2	Principal normal strains - calculated
F	Working variable
G	Inverse matrix
I2	Set to 1 to include a linear elastic term in the series characterization otherwise leave blank or zero - input
I3	Number of power or prony series terms - input
I4	$I2 + I3$ - calculated

I6	Equal to NTEMP - Calculated
INV1	First strain invariant - input
JL	Total number of input data points - calculated
KFL	Number of input data points in a particular test - calculated
KODE	Test type: = 0 for uniaxial; = 1 for shear; = 2 for biaxial stop - input
LLL	Characterization type: = 0 for power series; = 1 for prony series - input
NN	Exponent in the power series term $(1 + Bt)^{NN}$ - input
NEXP	Number of data points for this test - input
NTEMP	Number of shift function vs temperature pairs - input, 20 max.
NTESTS	Number of tests for this run - input
RATE	Incremental strain rate - input
SIG1	Working array to store all stress input
STD	Standard deviation - calculated
STRN1	Same as SIG1 except for strain - calculated
T	Time - calculated
TEM	Same as SIG1 except for temperature - calculated
TEMP	Temperature at a data point - input
TIME	Output time - calculated
TITLE	80 column alphanumeric identification - input
TR	Reduced time - calculated
TTEMP	Shift function input temperature - input
V	Working matrix
VOLUME	Same as SIG 1 except for INV1 - calculated

X	Dummy array
XBAR	Average error - calculated
XF	Union of the X sets
Y	Observed stress - input
YCAL	Calculated stress - output

## 2.2 DATA INPUT

The input variable required by LINVIS are shown below, card by card, with the format shown in parentheses.

Card 1 (20A4) TITLE

Card 2 (E10.0) BETA

Card 3 (5I5) I2, I3, LLL, NTESTS, NTEMP

Card(s) 4 (2E10.0) NN, B

Card(s) 5 (2E10.0) TTEMP, AT

Card 6 (2I5) NEXP, KØDE

Card(s) 7 (5E10.0) TEMP, RATE, DT, Y, INV1

Cards 1 through 5 are read only once per run.

Cards 6 and 7 are repeated for each test.

The above cards are shown on the data sheet below.

2.3 Shown below are the sample input sheets for a typical problem. By referring to the master data sheet, above, the input is self explanatory. The output sheets for this sample problem follow the data sheets.

## 2.4 PROGRAM LISTING

A complete source listing follows the sample problem output.



SAMPLE MINT - LUNARS

CARD NO.									
LUNAR SAMPLE PROBLEM									
1	1	3	1	2	7				
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24 MAY 73 15:10:08 PAGE 30

LINEAR VISCOELASTIC CHARACTERIZATION CONF  
LIVIS SAMPLE PROBLEM

PAGE 1

BETA = .1800-03

THIS IS A PRONY SERIES CHARACTERIZATION

THE FOLLOWING IS A LIST OF THE EXPONENTS, H(I), FOR THE GENERAL PRONY SERIES TERM EXP(-H\*I) ...

1 B(I)

1 .1000-01  
2 .1000+01  
3 .1000+03

V0101AY.025767.2.200

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LINEAR VISCOELASTIC CHARACTERIZATION CODE

PAGE 2

LINVIS SAMPLE PROBLEM

INPUT SHIFT FUNCTION, AT, VS. TEMPERATURE, TTFPP ...

I	AT(I)	TTFPP(I)
1	.1000+09	-.6500+02
2	.1500+07	-.4000+02
3	.6000+05	-.2000+02
4	.3000+04	.0000
5	.2800+02	.4000+02
6	.1000+01	.7700+02
7	.2500+00	.1000+03
8	.3000-01	.1400+02
9	.1000-01	.1600+03

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PAGE 3

LINEAR VISCOELASTIC CHARACTERIZATION CONF  
LINVIS SAMPLE PROGRAM

TEST NO. 1

10 INPUT DATA POINTS

DATA IS FROM A U N I A X I A L TEST

I	TEMP(I)	RATE(I)	DT(I)	Y(I)	YINV(I)
1	.0000	.0000	.0000	.0000	.0000
2	.1500+03	.5000+00	.9000-01	.1450+02	.0000
3	.1500+03	.5000+00	.5000-01	.2170+02	.1000+00
4	.1500+03	.5000+00	.5000-01	.2700+02	.3500+00
5	.1500+03	.5000+00	.5000-01	.2980+02	.6000+00
6	.1500+03	.5000+00	.5000-01	.3000+02	.1500+01
7	.1500+03	.5000+00	.5000-01	.3000+02	.2350+01
8	.1500+03	.5000+00	.5000-01	.3030+02	.3250+01
9	.1500+03	.5000+00	.5000-01	.2960+02	.4200+01
10	.1500+03	.5000+00	.5000-01	.2830+02	.5150+01

VRONAY-4,5767,2,200

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LINEAR VISCOELASTIC CHARACTERIZATION CODE

LINVIS SAMPLE PROBLEM

TEST NO. 2

12 INPUT DATA POINTS

DATA IS FROM A UNIAIAL TEST

I	TEMP(I)	RATE(I)	DT(I)	Y(I)	INVI(I)
1	.0000	.0000	.0000	.0000	.0000
2	.1500+03	.1250+01	.3200-01	.1300+02	.0000
3	.1500+03	.1250+01	.1600-01	.2100+02	.3000-01
4	.1500+03	.1250+01	.2000-01	.2800+02	.1700+00
5	.1500+03	.1250+01	.2000-01	.3400+02	.4000+00
6	.1500+03	.1250+01	.2000-01	.3670+02	.1020+01
7	.1500+03	.1250+01	.2000-01	.3760+02	.1750+01
8	.1500+03	.1250+01	.2000-01	.3770+02	.2600+01
9	.1500+03	.1250+01	.2000-01	.3730+02	.3550+01
10	.1500+03	.1250+01	.2000-01	.3670+02	.4520+01
11	.1500+03	.1250+01	.4000-01	.3500+02	.6600+01
12	.1500+03	.1250+01	.4000-01	.3250+02	.8500+01

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PAGE 5

# STATISTIC CHARACTERIZATION CONF

IR-VIS SAMPLE PROFILE

## REGRESSION ANALYSIS PRIMARY MATRIX

COLUMN 1	.114964-02	.101666-02	.642704-04	.646343-04
COLUMN 2	.101666-02	.902272-03	.591309-04	.595012-06
COLUMN 3	.642704-04	.591309-04	.668985-05	.681803-07
COLUMN 4	.646343-06	.595012-06	.681803-07	.695302-09

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24 MAY 73 15:10:00 PAGE 00

LINEAR VISCOELASTIC CHARACTERIZATION CODE

PAGE 6

LINVIS SAMPLE PROFILE

REGRESSION ANALYSIS X BY Y COLUMN VECTOR

.1434E+00

.128707+00

.907670-02

.995743-04

04/04/2004 15:27:10.00

20 MAY 73 15:31:00 1000

L I N E A R V I S C O E L A S T I C C H A R A C T E R I Z A T I O N C O R R  
L I N E A R S A M P L E P R O B L E M

PAGE 7

REGRESSION ANALYSIS INVERSE MATRIX

COLUMN 1	.729859+06	-.886369+06	.127120+08	-.116647+10
COLUMN 2				
COLUMN 3	-.886369+06	.108056+07	-.162164+08	.148942+10
COLUMN 4	.127120+08	-.162164+08	.606891+08	-.574503+11
	-.116647+10	.148942+10	-.574503+11	.584466+13

**Price** per lb.

### LIVING SAMPLE PROGRAM

TEST NO. 1	10 INPUT DATA POINTS
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
10	10

DATA IS FROM A UNITARY ANAL. TEST

TEMP	TIME	STAIN	VOLUME	SIGCAL	SIGI	DEV	XF(1)	XF(2)	XF(3)	XF(4)	XF(5)
150.00000	000000	000000	000000	13.67	14.50	-5.72	72985-01	69035-01	87303-02	87324-04	
150.00000	900000	450000-01	000000	16.46	21.70	-24.16	11034+00	10344+00	84241-02	84241-04	
150.00000	1400000	700000-01	000000-02	18.09	27.00	-30.02	14557+00	13327+00	80057-02	80041-04	
150.00000	1900000	950000-01	350000-02	21.04	29.00	-29.41	17876+00	16003+00	77222-02	77200-04	
150.00000	2400000	1200000+00	000000-02	22.91	30.00	-25.62	21004+00	18372+00	73369-02	73344-04	
150.00000	2900000	1450000+00	150000-01	22.91	30.00	-20.09	24014+00	20516+00	70706-02	70700-04	
150.00000	3400000	1700000+00	235000-01	24.69	30.00	-12.76	26936+00	22489+00	65088-02	65081-04	
150.00000	3900000	1950000+00	325000-01	26.93	30.30	-5.18	29783+00	28308+00	62072-02	62067-04	
150.00000	4400000	2200000+00	470000-01	28.07	29.60	4.72	32573+00	25908+00	67308-02	67300-04	
150.00000	4900000	2450000+00	515000-01	29.64	28.30						

ELASTIC CHARACTERIZATION CONF

PAGE 9

LINIS SAMPLE PROBLEM

TEST NO. 2 12 INPUT DATA POINTS

DATA IS FROM A UNIAIAL TEST

TEMP	TYPE	STRESS	VOLUME	SIGCAL	SIGI	DEV	XF(1)	XF(2)	XF(3)	XF(4)	XF(5)
150.00000	.00000	.00000	.00000	.00	.00	.00	.00000	.00000	.00000	.00000	.00000
150.00000	.30000-01	.40000-01	.00000	13.41	13.40	-2.70	.65107-01	.64150-01	.20800-01	.21926-03	.21926-03
150.00000	.40000-01	.60000-01	.30000-03	24.40	21.00	16.18	.95687-01	.93506-01	.21104-01	.21421-03	.21421-03
150.00000	.60000-01	.85000-01	.17000-02	26.13	28.90	.80	.13195+00	.12764+00	.20670-01	.20660-03	.20660-03
150.00000	.80000-01	.11000+00	.40000-02	31.85	34.00	-6.32	.16611+00	.15545+00	.10872-01	.10760-03	.10760-03
150.00000	.10000+00	.13500+00	.10200-01	33.08	36.70	-7.40	.19827+00	.18653+00	.10052-01	.10043-03	.10043-03
150.00000	.12000+00	.16000+00	.17500-01	35.64	37.60	-5.22	.22891+00	.21558+00	.10159-01	.10063-03	.10063-03
150.00000	.14000+00	.18500+00	.26000-01	37.17	37.70	-1.41	.25844+00	.24107+00	.17578-01	.17510-03	.17510-03
150.00000	.16000+00	.21000+00	.35500-01	38.84	37.30	4.12	.28707+00	.26520+00	.17101-01	.17050-03	.17050-03
150.00000	.18000+00	.23500+00	.45200-01	40.41	36.70	10.10	.31508+00	.28830+00	.16926-01	.16810-03	.16810-03
150.00000	.20000+00	.28500+00	.66000-01	43.85	35.00	25.28	.36933+00	.33175+00	.16306-01	.16301-03	.16301-03

VOLUME 4. 6767.2.200

24 MAY 73 10:10:10 PAGE 40

L I F E V I S C O E L A S T I C C H A P A C T I F I C A T I O N C O R P  
L I V I S S A M P L E P R O B L E M

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TEST NO. 2

12 INPUT DATA POINTS

DATA IS FROM A U N I A X I A L T E S T

TIME	ST.01	VOLUME	SIGCAL	SIG1	DEV	XF(1)	XF(2)	VF(3)	XF(4)	VF(5)
150.00000	.26400+00	.33500+00	.85000-01	47.19	32.50	45.83	.42191+00	.37215+00	.16187-01	.16193-03

VRONAY, 425767, 2, 200

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LINEAR VISCOELASTIC CHARACTERIZATION CODE

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LINVIS SAMPLE PROBLEM

REGRESSION COEFFICIENTS ...

I CO(I)

1 .13006+02  
2 .75592+02  
3 .97668+04  
4 -.89129+06

THREE WERE 22 EXPERIMENTAL TEST POINTS

THE AVERAGE DEVIATION, X P A R , WAS -.0314

THE STANDARD DEVIATION, S T D , WAS .1785

DATA CARDS IGNORED - FIRST IS LISTED BELOW

\* ELT LINVIS.1,730521, 39540

000001	C	LINEAR VISCOELASTIC CHARACTERIZATION CODE WITH DILATATION FOR	A 10
000002	C	DEVIATORIC STRESSES USING MODIFIED POWER SERIES OR PRONY SERIES	A 20
000003	C	AT = VECTOR OF SHIFT FUNCTION VALUES ASSOCIATED WITH ITEM	A 30
000004	C	AVGAT = VALUE OF SHIFT FUNCTION FOR A SPECIFIC TIME.	A 40
000005	C	B = CONSTANT IN THE POWER SERIES TERM (1+PT)**N, OR THE	A 50
000006	C	EXPONENT IN THE PRONY SERIES TERM EXP(-RT).	A 60
000007	C	A COLUMN VECTOR IN THE REGRESSION EQUATION.	A 70
000008	C	VOLUMETRIC EXPANSION COEFFICIENT.	A 80
000009	C	REGRESSION COEFFICIENTS.	A 90
000010	C	INTERPOLATION SLOPE FOR SHIFT FUNCTION, AT.	A 100
000011	C	PERCENT DEVIATION BETWEEN EXPERIMENTAL AND CALCULATED	A 110
000012	C	DEVIAT = DEFINED AS (OE11-E22)/DT.	A 120
000013	C	DT = DELTA TIME BETWEEN EXPERIMENTAL INPUT POINTS.	A 130
000014	C	STRAINS E11 AND E22 RESPECTIVELY.	A 140
000015	C	F = FRONT FACTOR TO INCLUDE TEMPERATURE DEPENDENCE OF MO	A 150
000016	C	TO CORRECT FOR TRUE STRESS.	A 160
000017	C	G = INVERSE MATRIX.	A 170
000018	C	IP = SET TO 1 IF IT IS DESIRED TO INCLUDE A LINEAR ELASTIC	A 180
000019	C	IN THE SERIES CHARACTERIZATION.	A 190
000020	C	I3 = NUMBER OF TERMS OF THE POWER OR PRONY SERIES.	A 200
000021	C	I4 = I2 + I3	A 210
000022	C	IG = NTMP	A 220
000023	C	INV1 = FIRST STRAIN INVARIANT, EKK = E11+E22+E33 = DV/V.	A 230
000024	C	INV2 = SECOND STRAIN INVARIANT (NOT USED THIS CONF).	A 240
000025	C	JL = TOTAL NUMBER OF OUTPUT POINTS EQUALS TOTAL NUMBER OF	A 250
000026	C	EXPERIMENTAL INPUT POINTS.	A 260
000027	C	KEL = NUMBER OF EXPERIMENTAL INPUT DATA POINTS FROM A PART	A 270
000028	C	TEST, "MAXIMUM" = 50.	A 280
000029	C	KODE = TYPE OF TEST INPUT DATA: 0 FOR UNIAXIAL	A 290
000030	C	1 FOR SHEAR	A 300
000031	C	2 FOR RIAXIAL STRIP (E33	A 310
000032	C	= 0 FOR POWER SERIES (1+RT)	A 320
000033	C	= 1 FOR PRONY SERIES EXP(-RT)	A 330
000034	C	EXPONENT IN THE POWER SERIES TERM (1+RT)**N.	A 340
000035	C	NUMBER OF EXPERIMENTAL INPUT DATA POINTS FROM THIS T	A 350
000036	C	NUMBER OF INPUT SHIFT FUNCTION/TEMPERATURE DATA POINT	A 360
000037	C	MAXIMUM IS 20.	A 370
000038	C	TOTAL NUMBER OF TESTS INPUT FOR THIS RUN, MAXIMUM =	A 380
000039	C	INCREMENTAL STRAIN RATE.	A 390
000040	C	SIG1 = MEASURED VALUES OF STRESS INPUT FOR ALL TESTS, MAXIM	A 400
000041	C	SIG = STANDARD DEVIATION	A 410
000042	C	STRA1 = STRAIN EFFLON-11.	A 420
000043	C	T = EXPERIMENTAL INPUT TIME POINTS, 50 MAXIMUM.	A 430
000044	C	TEMP = TEMPERATURE.	A 440
000045	C	TEMP = TEMPERATURE FOR INPUT DATA.	A 450
000046	C	TIME = CALCULATED OUTPUT POINTS, 600 MAXIMUM.	A 460
000047	C	TIME = 80 COLUMN IDENTIFICATION	A 470
000048	C	TR = REDUCED TIME, DEFINED AS DT/AT.	A 480
000049	C	VECTOR OF TEMPERATURE VALUES CORRESPONDING TO INPUT	A 490
000050	C	OF THE SHIFT FUNCTION AT.	A 500
000051	C	V = MATRIX GENERATED FOR REGRESSION ANALYSIS.	A 510
000052	C	VOLUME = DILATATION, SAME AS INV1.	A 520
000053	C	X = EQUATION VARIABLES FOR A PARTICULAR TEST.	A 530
000054	C	XRA = AVERAGE DEVIATION	A 540
000055	C	XF = COLLECTION OF VARIABLES FOR ALL TESTS, THE UNION OF	A 550
000056	C	THE X SETS.	A 560

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C Y YCAL = ORSERVO STRESS INPUT FOR A PARTICULAR TEST, MAXIMUM A 570
C YCAL = CALCULATION STRESS CORRESPONDING TO AN EXPERIMENTAL I A 580
C DATA POINT. A 590
C DIMENSION AT(20), AVGRAT(50), R(14), RB(15), CO(15), N(20), A 600
1 DEURAT(50), RT(50), E1(50), F2(50), F(50), G(15,15), A 610
2 INVI(50), TMV2(50), KORE(50), NEVP(50), IN(14), A 620
3 RATE(50), STG1(600), T(50), TFM(600), A 630
4 TEMP(50), TAVE(600), TITLE(20), TR(50), TTEMP(20), A 640
5 V(15,15), VOLUPE(600), X(15,50), YF(15,600), Y(50) A 650
C MODIF PRECISION INT,X,YF
C REAL IN, INVI
C *** FORMAT STATEMENTS ***
C
C
1 FORMAT (1H,40X, 'THIS IS A POWER LAW CHARACTERIZATION, //',1CY,
1 THE FOLLOWING IS A LIST OF THE CONSTANTS, R(1), AND EXPONENTS, N
2,1), FOR THE GENERAL POWER SERIES TERM (1 + P*1), AND EXPONENTS, N
3,10X, I, 20X, T(1), 20X, T(1), 20X, T(1), 20X, T(1), 20X, T(1),
4 FOR AT (1H,40X, 'THIS IS A POWER SERIES CHARACTERIZATION, //',1CY,
5 THE FOLLOWING IS A LIST OF THE EXPONENTS, R(1), FOR THE GENERAL
6 POWER SERIES TERM EXP(-R*1) ...., //',10X, I, 20X, R(1
7), // )
C
3 FORMAT (16IS)
4 FOR AT (16IS)
5 FOR AT (1H,10X, I, 20X, F10.4 )
6 FOR AT (20A4)
7 FOR AT (1H, 7X, 15, 2(20X, F10.4) )
8 FOR AT (1H, 10X, 'COLUMN 14, 1, 3(20X, F520.6, //), // )
9 FOR AT (1H, //',10X, 'INPUT SHIFT FUNCTION, AT, VS. TEMPERATURE,
10 TTEMP, //',10X, I, 20X, AT(1), 20X, TTEMP(1), // )
C
10 FOR AT (1H, 50X, 'DATA = F10.4, / )
11 FOR AT (1H,10X, I, 20X, TTEMP(1), 20X, RATE(1), 20X, RT(1),
12 T(1), Y(1), T(1), T(1), T(1), // )
13 FOR AT (1H,10X,13,2X, 5(10X, F10.4) )
14 1/ 40X, 'DATA IS FROM A UH I A T A L TEST, // )
15 1/ 40X, 'DATA IS FROM A SH F A R TEST, // )
16 1/ 40X, 'DATA IS FROM A R I A X I A L S T I P TEST, // )
17 1/ 40X, 'DATA IS FROM A V I S C O E L A S T I C C H A R A C T
18 E, T A T O H C O D E, T(10), PAGE, 14, //, 30X, 20A4, // )
19 FOR AT (1H, //',10X, 'REGRESSION COEFFICIENTS, //',12X, I, 26X,
20 'CO(1), //',15(11X,12,2X, F12.5, //), 10(1) )
21 FOR AT (1H, //',15X, 'TEMP, 6X, TTEMP, 5X, 'STG1, 4X, 'VOLUPE, 6X,
22 'SIGAL, 5X, 'STG1, 7X, 'NEVP, 5(15X,11.1, // )
23 FOR AT (1H,1Y,F0.5, F10.5, 3F10.2, 5E10.5, 2(7Y,1X, F10.5), / )
24 1 10X, 'THE AVERAGE DEVIATION, S D, WAS, F10.4, //',10
25 2X, 'THE STANDARD DEVIATION, S D, WAS, F10.4 )
26 FOR AT (1H,10(1),30X,76(1), //,50X, 'INVERSE FAILED ON ROW, 14,
27 //,30X,76(1), 10(1),50X, 'PROGRAM TERMINATED' )
28 FOR AT (1H, 4(1),30X, 'REGRESSION ANALYSIS PRIMARY MATRIX, //')
29 FOR AT (1H, 10X, 'REGRESSION ANALYSIS X BY Y COLUMN VECTOR, //',
30 3(10X, F20.6, // )
31 FOR AT (1H, 30X, 'REGRESSION ANALYSIS INVERSE MATRIX, //')
32 4E4( 5.6) (TITLE(1),1E1,20)

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001177 Y(K)=0. A1770
001178 F1(K)=0. A1780
001179 TEMP(K)=0. A1790
001180 INV(K)=0.0 A1800
001181 INV1(K)=0.0 A1810
001182 DT(K)=0. A1820
001183 TR(K)=0. A1830
001184 F2(K)=0. A1840
001185 DEVGAT(K)=0. A1850
001186 F(K)=0. A1860
001187 AVGAT(K)=0. A1870
001188 DO 33 J=1,15 A1880
001189 X(J,K)=0.00 A1890
001190 CONTINUE A1900
001191 PEA(15,3)=EXP(NT), KODE(NT) A1910
001192 KLE=EXP(NT)*I A1920
001193 IPG=IPG+1 A1930
001194 WRITE(6,16) IPG, (TITLE(I),I=1,20) A1940
001195 IF (KODE(11).EQ.0) WRITE(6,13) NT, KFL A1950
001196 IF (KODE(11).EQ.1) WRITE(6,14) NT, KFL A1960
001197 IF (KODE(11).EQ.2) WRITE(6,15) NT, KFL A1970
001198 WRITE(6,11) A1980
001199 DO 34 K=2,KFL A1990
001200 ZK=1 A2000
001201 PEA(15,4)=TEMP(K), RATE(K), DT(K), Y(K), INV1(K) A2010
001202 WRITE(6,12) M, TEMP(M), RATE(M), DT(M), Y(M), INV1(M) A2020
001203 CONTINUE A2030
001204 WRITE(6,12) K, TEMP(K), RATE(K), DT(K), Y(K), INV1(K) A2040
001205 A2050
001206 A2060
001207 INV1(K)=INV1(K)/100. A2070
001208 T(K)=(K-1)+DT(K) A2080
001209 INV1(K)=INV1(K)+SEITA*(TEMP(K)-TEMP(2)) A2090
001210 F1(K)=F1(K-1)+RATE(K)*DT(K) A2100
001211 F2(K)=0.5*(INV1(K)-F1(K)) A2110
001212 IF (KODE(11).EQ.1) F2(K)=0.0 A2120
001213 IF (KODE(11).EQ.2) F2(K)=2.*F2(K) A2130
001214 DEV.AT(K)=RATE(K)-(F2(K)-F2(K-1))/DT(K) A2140
001215 CONTINUE A2150
001216 A2160
001217 A2170
001218 A2180
001219 DO 31 K=2,KFL A2190
001220 IF (K.FO.2) GO TO 36 A2200
001221 FPS=AFS(TEMP(K))-ABS(TEMP(K-1)) A2210
001222 FPS=AFS(FPS) A2220
001223 IF (FPS.LT.1.E-1) GO TO 39 A2230
001224 DO 37 J=1,16 A2240
001225 IF (TEMP(K).LT.TTEMP(J)) GO TO 3A A2250
001226 CONTINUE A2260
001227 AVG.AT(K)=(EXP(LOG(AT(J-1))+DT(J)*(TEMP(K)-TTEMP(J-1)))) A2270
001228 GO TO 40 A2280
001229 AVGAT(K)=AVGAT(K-1) A2290
001230 TR(K)=TR(K-1)+DT(K)/AVGAT(K) A2300
001231 F(K)=(TEMP(K)+450.4)/540.1*(1.+INV1(K))/(1.+F1(K)) A2310
001232 X1(K)=(F1(K)+F2(K))*F(K) A2320
001233 CONTINUE A2330
001234 IF (LLC.FO.1) GO TO 44 A2340
001235 C A2350
001236 C A2360

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COMPUTE POWER SERIES TERMS.

```

000227 C
000228 DO 43 M=1,I3
000229 DO 42 J=2,KFL
000230 A3=0/(M)*I1.
000231 THT=0.
000232 DO 42 K=2,J
000233 THT=INT-(DEVPAT(K)/(R(M)*A3))*((I)+R(M))*((TR(J)-TR(K)))*A3-
000234 1+R(M))*((TR(J)-TR(K-1)))*A3)+AVGAT(K)
000235 CONTINUE
000236 X(I2+J,J)=INT+THT
000237 CONTINUE HA2460
000238 GO TO 47
000239 C
000240 C COMPUTE PRONY SERIES TERMS.
000241 C
000242 DO 46 M=1,I3
000243 DO 45 J=2,KFL
000244 THT=0.
000245 DO 45 K=2,J
000246 THT=INT+((AVGAT(K)+DEVPAT(K))/R(M))*((I)+R(M))*((TR(J)-TR(K)))-
000247 1*EXP(-(M))*((TR(J)-TR(K-1))))
000248 CONTINUE
000249 X(I2+J,J)=INT+THT
000250 CONTINUE
000251 C
000252 C LOAD LOCAL VECTORS INTO GLOBAL VECTORS.
000253 C
000254 CONTINUE
000255 DO 44 M=1,KFL
000256 STG1(JL+M)=F1(M)
000257 T1(JL+M)=Y(M)
000258 T1(JL+K)=I(K)
000259 VOL+((JL+K)=TRV1(K)
000260 TR(JL+K)=TRV1(K)
000261 DO 44 M=1,I4
000262 XFC(JL+K)=X(M,K)
000263 CONTINUE
000264 JLE=JL+KFL
000265 CONTINUE
000266 JI=I4
000267 C
000268 C REGRESSION ANALYSIS.
000269 C
000270 DO 51 K=1,I1 P7A0
000271 DO 51 J=1,I1
000272 SAE=0.
000273 DO 50 I=1,J
000274 IF (SIG1(I),LT,1.) GO TO 50
000275 SAE=SAE+XFC(K,I)*XF(J,I)/SIG1(I)**2.
000276 CONTINUE
000277 V(X,J)=SAE
000278 CONTINUE
000279 DO 53 K=1,I1
000280 PR(K)=0.
000281 DO 52 I=1,J
000282 IF (SIG1(I),LT,1.) GO TO 52
000283 PR(K)=PR(K)+XF(K,I)*SIG1(I)/SIG1(I)**2.
000284 CONTINUE
000285 DO 54 I=1,I1
000286 C
000287 C
000288 C
000289 C
000290 C
000291 C
000292 C
000293 C
000294 C
000295 C
000296 C

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000297	00 54 J=1,11	A2970
000298	G(I,J)=V(I,J)	A2980
000299	IPG=IPG+1	A2990
000300	WRITE (6,16) IPG, (TITLE(I),I=1,20)	A3000
000301	WRITE (6,23)	A3010
000302	00 55 J=1,11	A3020
000303	WRITE (6,16) J, (V(I,J),I=1,11)	A3030
000304	IPG=IPG+1	A3040
000305	WRITE (6,16) IPG, (TITLE(I),I=1,20)	A3050
000306	WRITE (6,23) (M(J),J=1,11)	A3060
000307		A3070
000308	C COMPUTE INVERSE.	A3080
000309		A3090
000310	IF=1	A3100
000311	DO 56 K=1,11	A3110
000312	COM=G(K,K)	A3120
000313	IF (CODE.EQ.0.0) GO TO 60	A3130
000314	G(K,K)=1.	A3140
000315	DO 56 J=1,11	A3150
000316	G(K,J)=G(K,J)/COM	A3160
000317	00 59 I=1,11	A3170
000318	IF (I-K) 57,59,57	A3180
000319	COM=G(I,K)	A3190
000320	G(I,K)=0.	A3200
000321	00 56 J=1,11	A3210
000322	G(I,J)=G(I,J)-COM*G(K,J)	A3220
000323	CONTINUE	A3230
000324	GO TO 61	A3240
000325	DO 56 K=1,11	A3250
000326	DO 56 J=1,11	A3260
000327	IPG=IPG+1	A3270
000328	WRITE (6,16) IPG, (TITLE(I),I=1,20)	A3280
000329	WRITE (6,23) NCF	A3290
000330	CALC EXIT	A3300
000331	CONTINUE	A3310
000332	IPG=IPG+1	A3320
000333	WRITE (6,16) IPG, (TITLE(I),I=1,20)	A3330
000334	WRITE (6,24)	A3340
000335	00 52 J=1, 11	A3350
000336	WRITE (6,16) J, (G(I,J),I=1,11)	A3360
000337	CONTINUE	A3370
000338		A3380
000339	C COMPUTE REGRESSION COEFFICIENTS.	A3390
000340		A3400
000341	00 53 K=1,11	A3410
000342	CO(K)=0.	A3420
000343	00 53 I=1,11	A3430
000344	CO(K)=CO(K)+G(K,I)*RP(I)	A3440
000345	CONTINUE	A3450
000346	IF=1	A3460
000347	KFL=EXP(N)+1	A3470
000348	IPG=IPG+1	A3480
000349	WRITE (6,16) IPG, (TITLE(I),I=1,20)	A3490
000350	IF (CODE(H).EQ.0) WRITE (6,13) N, KFL	A3500
000351	IF (CODE(N).EQ.1) WRITE (6,14) N, KFL	A3510
000352	IF (CODE(H).EQ.2) WRITE (6,15) N, KFL	A3520
000353	WRITE (6,18) (I,I=1,5)	A3530
000354		A3540
000355	C CALCULATE STRESS AT INPUT POINTS.	A3550
000356		A3560

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000357 LITZ=3 A3570
000358 SUM=0. A3580
000359 PFSIN=0. A3590
000360 N=0 A3600
000361 N0 07 I=1,JL A3610
000362 N=0+1 A3620
000363 IF (N*LF,KFL) GO TO 64 A3630
000364 JEN+1 A3640
000365 XFL=EXP2(N)+1 A3650
000366 LITZ=50 A3660
000367 N=1 A3670
000368 CONTINUE A3680
000369 LITZ=LITZ+3 A3690
000370 IF (LITZ,LT,13) GO TO 65 A3700
000371 IPG=IPG+1 A3710
000372 LITZ=0 A3720
000373 WRITE (6,16) IPG, (TITLE(L),L=1,20) A3730
000374 IF (KOF(4),FC,1) WRITE (6,13) N, KFL A3740
000375 IF (KOF(4),FC,1) WRITE (6,14) N, KFL A3750
000376 IF (KOF(4),FC,2) WRITE (6,15) N, KFL A3760
000377 WRITE (6,16) (PFL, KFL=1,5) A3770
000378 CONTINUE A3780
000379 YCAL=0.6 A3790
000380 DO 56 J=1,11 A3800
000381 YCAL=YCAL+G(J)*XF(J,7) A3810
000382 DEVI=100.+(YCAL-STG1(T))/STG1(T) A3820
000383 WRITE (6,19) T, (I, I=1,11)*VOLUME(I),YCAL,STG1(T),DEV, A3830
000384 1 (X(J),J=1,11) A3840
000385 IF (G1C1(I),LT,1) GO TO 67 A3850
000386 G1G1=DEV*STG1*CFV**2./10.**4. A3860
000387 G1V=CLV*DEV/100. A3870
000388 CONTINUE A3880
000389 G1A=50K/JL A3890
000390 STG2=((CL*F5*10-SUM**2.)/(JL*(J-1)))**0.5 A3900
000391 IPG=IPG+1 A3910
000392 WRITE (6,16) IPG, (TITLE(I),I=1,20) A3920
000393 WRITE (6,17) (Y, COI), I=1,11 A3930
000394 WRITE (6,20) JL, YEAR, STD A3940
000395 STOP A3950
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## APPENDIX H

### SAMPLES OF EXPERIMENTAL DATA

This appendix lists some of the experimental data obtained on ANB-3335-1 propellant at 0°F. These data are from "pressurized" uniaxial and biaxial experiments. In total over 250 experiments of the type illustrated were performed on this propellant at temperatures from -65°F to +150°F and pressures from atmospheric to 1000 psi. After processing the raw data through the Preprocessor Code NL001, calculated stress-strain-invariant histories are stored on magnetic tape. The experimental data listed in this appendix represents only a partial listing of the calculated information from each experiment. These listings were obtained using the Post Processor Code.

These data are illustrated in this appendix to demonstrate the type of experimental data obtained and used on this contract. Arrangements can be made to obtain a copy of the complete magnetic tape data file for those who are interested in testing theory against real data.

# SUMMARY OF TEST NO. UN0600

PAGE UN0600 - 3

## MATERIAL DATA

MATERIAL IS: ABR 3335-1

BULK MODULUS = .5000+06

VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

## TEST DATA

TYPE ... UNIAXIAL

INITIAL STRAIN RATE = .4700+00

PRESSURE = 0. PSIG

TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	F11	F22	E33	E12	TRIF STRESS (S11 - S22)
1	.000	0.	.0000	.0000	.0000	.0000	.0000
2	.180+01	0.	.2030-01	-.0852-02	-.0852-02	.0000	.4000+02
3	.360+01	0.	.4101-01	-.1804-01	-.1804-01	.0000	.7500+02
4	.540+01	0.	.7642-01	-.3202-01	-.3202-01	.0000	.1265+03
5	.900+01	0.	.1129+00	-.4435-01	-.4435-01	.0000	.1668+03
6	.120+02	0.	.1506+00	-.5378-01	-.5378-01	.0000	.1800+03
7	.150+02	0.	.1894+00	-.6140-01	-.6140-01	.0000	.2036+03
8	.186+02	0.	.2293+00	-.6736-01	-.6736-01	.0000	.2115+03
9	.216+02	0.	.2703+00	-.7219-01	-.7219-01	.0000	.2168+03
10	.246+02	0.	.3124+00	-.7508-01	-.7508-01	.0000	.2207+03
11	.276+02	0.	.3557+00	-.7957-01	-.7957-01	.0000	.2233+03
12	.306+02	0.	.4001+00	-.8262-01	-.8262-01	.0000	.2248+03
13	.336+02	0.	.4456+00	-.8551-01	-.8551-01	.0000	.2241+03
14	.366+02	0.	.4922+00	-.8792-01	-.8792-01	.0000	.2223+03
15	.396+02	0.	.5400+00	-.9160-01	-.9160-01	.0000	.2126+03

# SUMMARY OF TEST NO. UN0600

PAGE UN0600 - 2

## MATERIAL DATA

MATERIAL IS ABR 3335-1  
 PULP MODULUS = .5000+06  
 VOLUMETRIC EXPANSION COEFFICIENT = .1800-03  
 TYPE ... INITIAL  
 INITIAL STRAIN RATE = .6700+00  
 PRESSURE =  
 TEMPERATURE IS CONSTANT

## TEST DATA

DATA POINT	TIME SEC.	STRAIN INVARIANTS			CORRECTED DILATATION	OCTAHEDRAL STRAIN
		I1	I2	I3		
1	.000	.0000	.0000	.0000	.0000	.0000
2	.180+01	.5981-03	-.5030-03	.1971-05	.2030-07	.1821-01
3	.360+01	.3323-02	-.1190-02	.1454-04	.1000-02	.2821-01
4	.600+01	.1057-01	-.3048-02	.8283-04	.3000-02	.5154-01
5	.960+01	.2425-01	-.9051-02	.2221-03	.9000-02	.7815-01
6	.126+02	.4303-01	-.1331-01	.4356-03	.1800-01	.9635-01
7	.156+02	.6657-01	-.1049-01	.7140-03	.3000-01	.3182+00
8	.186+02	.9455-01	-.2635-01	.1040-02	.4500-01	.1308+00
9	.216+02	.1259+00	-.3391-01	.1409-02	.6200-01	.1614+00
10	.246+02	.1605+00	-.4170-01	.1800-02	.8100-01	.1831+00
11	.276+02	.1965+00	-.5028-01	.2252-02	.1000+00	.2052+00
12	.306+02	.2348+00	-.5928-01	.2731-02	.1200+00	.2275+00
13	.336+02	.2746+00	-.6990-01	.3258-02	.1400+00	.2508+00
14	.366+02	.3164+00	-.7882-01	.3805-02	.1610+00	.2735+00
15	.396+02	.3568+00	-.9053-01	.4530-02	.1780+00	.2977+00

6 AND UN0601

SUMMARY OF TEST NO. 000601

MATERIAL DATA

MATERIAL IS ANR 3335-1  
 BULK MODULUS = 5000+06  
 VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... INITIAL  
 INITIAL STRAIN RATE = .4700+00  
 PRESSURE = 0. PSIF  
 TEMPERATURE IS CONSTANT

DATA POINT	TIME SFC.	TEMP. DEG.-F	STRAINS (CALCULATED)		TRUE STRESS (SI - 522)	
			F11	F22	E12	
1	.000	0.	.0000	.0000	.0000	.0000
2	.120+01	0.	.1349-01	-.6611-02	.0000	.2534+02
3	.240+01	0.	.2716-01	-.1305-01	.0000	.5955+02
4	.420+01	0.	.4800-01	-.2102-01	.0000	.1015+03
5	.720+01	0.	.8363-01	-.3536-01	.0000	.1506+03
6	.102+02	0.	.1204+00	-.4619-01	.0000	.1839+03
7	.132+02	0.	.1583+00	-.5421-01	.0000	.2134+03
8	.162+02	0.	.1973+00	-.6050-01	.0000	.2237+03
9	.192+02	0.	.2374+00	-.6563-01	.0000	.2306+03
10	.222+02	0.	.2786+00	-.6968-01	.0000	.2348+03
11	.252+02	0.	.3210+00	-.7312-01	.0000	.2380+03
12	.282+02	0.	.3645+00	-.7630-01	.0000	.2409+03
13	.312+02	0.	.4091+00	-.7913-01	.0000	.2437+03
14	.342+02	0.	.4548+00	-.8137-01	.0000	.2461+03
15	.372+02	0.	.5017+00	-.8346-01	.0000	.2486+03
16	.402+02	0.	.5497+00	-.8658-01	.0000	.2517+03

# SUMMARY OF TEST NO. UN0601

PAGE UN0601 - 2

## MATERIAL DATA

MATERIAL IS AMR 3335-1  
 BULK MODULUS = .500E+06  
 VOLUMETRIC EXPANSION COEFFICIENT = .180E-03

## TEST DATA

TYPE ... UNIAxIAL  
 INITIAL STRAIN RATE = .6700E+00  
 PRESSURE = 0. PSIG  
 TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	STRAIN INVARIANTS			CORRECTED DILATATION	OCTAHEDRAL STRAIN
		I1	I2	I3		
1	.000	.0000	.0000	.0000	.0000	.0000
2	.120+01	.2670-03	-.1347-03	.5896-06	.1346-07	.9476-02
3	.240+01	.1650-02	-.5386-03	.4625-05	.2716-07	.1866-01
4	.420+01	.4150-02	-.1624-02	.2307-04	.1000-02	.3296-01
5	.720+01	.1292-01	-.4664-02	.1046-03	.4000-02	.5400-01
6	.102+02	.2801-01	-.8688-02	.2568-03	.1100-01	.7852-01
7	.132+02	.4984-01	-.1822-01	.4651-03	.2300-01	.1002+00
8	.162+02	.7625-01	-.2021-01	.7221-03	.3800-01	.1315+00
9	.192+02	.1061+00	-.2685-01	.1022-02	.5500-01	.1422+00
10	.222+02	.1363+00	-.3397-01	.1353-02	.7400-01	.1442+00
11	.252+02	.1747+00	-.4160-01	.1716-02	.9400-01	.1858+00
12	.282+02	.2117+00	-.4985-01	.2127-02	.1140+00	.2078+00
13	.312+02	.2508+00	-.5848-01	.2562-02	.1350+00	.2301+00
14	.342+02	.2921+00	-.6740-01	.3012-02	.1570+00	.2528+00
15	.372+02	.3340+00	-.7711-01	.3528-02	.1780+00	.2760+00
16	.402+02	.3765+00	-.8768-01	.4121-02	.1980+00	.2990+00

END UN0602

# SUMMARY OF TEST NO. U00602

PAGE 000602 -

## MATERIAL DATA

MATERIAL IS AND 3374-1  
 BULK MODULUS = .5000+06  
 VOLUME FRICTION EXPANSION COEFFICIENT = .1800-03

## TEST DATA

TYPE ... UNIAxIAL  
 INITIAL STRAIN RATE = .1670+01  
 PRESSURE = 0. FATH  
 TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	F11	STRAIN (CALCULATED) E22	E12	TRUE STRESS (S11 - S22)
1	.000	0.	.0000	.0000	.0000	.0000
2	.420+01	0.	.1237+00	-.5233-01	.0000	.1574+02
3	.420+01	0.	.1425+00	-.5003-01	.0000	.1602+02
4	.540+01	0.	.1616+00	-.6533-01	.0000	.1601+03
5	.650+01	0.	.2006+00	-.7717-01	.0000	.1504+03
6	.780+01	0.	.2407+00	-.8817-01	.0000	.1904+03
7	.900+01	0.	.2619+00	-.9856-01	.0000	.2371+03
8	.102+02	0.	.2802+00	-.1074+00	.0000	.2671+03
9	.120+02	0.	.3004+00	-.1166+00	.0000	.2940+03
10	.150+02	0.	.5047+00	-.1356+00	.0000	.2364+03
11	.130+02	0.	.6265+00	-.1482+00	.0000	.2662+03
12	.210+02	0.	.7553+00	-.1624+00	.0000	.3154+03
13	.200+02	0.	.8011+00	-.1670+00	.0000	.3728+03
14	.270+02	0.	.1034+01	-.1760+00	.0000	.3831+03
15	.300+02	0.	.1184+01	-.1831+00	.0000	.3880+03
16	.330+02	0.	.1340+01	-.1893+00	.0000	.3866+03
17	.360+02	0.	.1504+01	-.1956+00	.0000	.3772+03

# SUMMARY OF TEST NO. 100602

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## MATERIAL DATA

MATERIAL IS AIR 3335-1  
 BULK MODULUS = .5000+00  
 VOLUME-TRIC EXPANSION COEFFICIENT = .1800-03

## TEST DATA

TYPE ... INITIAL  
 INITIAL STRAIN RATE = .1670+01  
 PRESSURE = 0. PCIC  
 TEMPERATURE IS CONSTANT

DATA POINT	TIME SFC.	STRAIN INVARIANTS			CORRECTED DILATATION	OCTAHEDRAL STRESS
		I1	I2	I3		
1	.000	.0000	.0000	.0000	.0000	.0000
2	.420+01	.1907-01	-.1021-01	.3389-03	.1237-06	.2300-01
3	.480+01	.2407-01	-.1332-01	.4949-03	.1425-06	.4807-01
4	.540+01	.3093-01	-.1685-01	.6907-03	.1616-06	.1070+00
5	.560+01	.4623-01	-.2500-01	.1105-02	.1000-02	.1300+00
6	.700+01	.6303-01	-.4072-01	.1879-02	.2000-02	.1551+00
7	.900+01	.8475-01	-.4585-01	.2738-02	.4000-02	.1703+00
8	.102+02	.1053+00	-.5912-01	.3743-02	.8000-02	.2035+00
9	.120+02	.1506+00	-.7801-01	.5572-02	.1500-01	.2601+00
10	.150+02	.2334+00	-.1185+00	.9283-02	.3300-01	.5018+00
11	.180+02	.3700+00	-.1638+00	.377-01	.5600-01	.8652+00
12	.210+02	.4306+00	-.2189+00	.1091-01	.7000-01	.4726+00
13	.240+02	.5584+00	-.2710+00	.2511-01	.1080+00	.4992+00
14	.270+02	.6819+00	-.3324+00	.5202-01	.1350+00	.5703+00
15	.300+02	.8174+00	-.3999+00	.3968-01	.1630+00	.6443+00
16	.330+02	.9616+00	-.4717+00	.4805-01	.1820+00	.7211+00
17	.360+02	.1113+01	-.5500+00	.5752-01	.2190+00	.8012+00

Q AND 000605

# SUMMARY OF TEST NO. U00605

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## MATERIAL DATA

MATERIAL NO. AND 3334-1  
 BULK MODULUS = 5000+06  
 VOLUMETRIC EXPANSION COEFFICIENT = .1000-03

## TEST DATA

TYPE -- INITIAL  
 INITIAL STRAIN RATE = .000+03  
 PRESSURE = 0. PSIG  
 TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	F11	F22	STRAINS (CALCULATED) E33	E12	TRUE STRESS (S11 - S22)
1	.000	0.	.0000	.0000	.0000	.0000	.0000
2	.120+01	0.	.6622-02	-.3278-02	-.3278-02	.0000	.2215+02
3	.420+01	0.	.2337-01	-.1120-01	-.1120-01	.0000	.5422+02
4	.660+01	0.	.3696-01	-.1703-01	-.1703-01	.0000	.7768+02
5	.102+02	0.	.5767-01	-.2561-01	-.2561-01	.0000	.1097+03
6	.162+02	0.	.9307-01	-.3841-01	-.3841-01	.0000	.1532+03
7	.222+02	0.	.1206+00	-.4861-01	-.4861-01	.0000	.1817+03
8	.282+02	0.	.1671+00	-.5675-01	-.5675-01	.0000	.1975+03
9	.342+02	0.	.2058+00	-.6317-01	-.6317-01	.0000	.2052+03
10	.402+02	0.	.2455+00	-.6801-01	-.6801-01	.0000	.2128+03
11	.462+02	0.	.2864+00	-.7180-01	-.7180-01	.0000	.2178+03
12	.522+02	0.	.3283+00	-.7540-01	-.7540-01	.0000	.2204+03
13	.582+02	0.	.3713+00	-.7884-01	-.7884-01	.0000	.2227+03
14	.642+02	0.	.4154+00	-.8133-01	-.8133-01	.0000	.2237+03
15	.702+02	0.	.4606+00	-.8336-01	-.8336-01	.0000	.2248+03
16	.762+02	0.	.5069+00	-.8741-01	-.8741-01	.0000	.2280+03
17	.822+02	0.	.5543+00	-.8980-01	-.8980-01	.0000	.2182+03
18	.882+02	0.	.6028+00	-.9185-01	-.9185-01	.0000	.2091+03

# SUMMARY OF TEST NO. UN0605

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## MATERIAL DATA

MATERIAL IS AIR 335-1

BULK MODULUS = .5000+06

VOLUOMETRIC EXPANSION COEFFICIENT = .1800-03

## TEST DATA

TYPE ... INITIAVAL

INITIAL STRAIN RATE = .3000+00

PRESSURE = 0. PCIC

TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	I1	STRAIN INVARIANTS I2	I3	CORRECTION DILATATION	OCTAHEDRAL STRAIN
1	.000	.0000	.0000	.0000	.0000	.0000
2	.120+01	.4505+04	-.3267-04	.7117-07	.6622-08	.4667-02
3	.420+01	.7084+03	-.4001-03	.2078-05	.2337-07	.1634-01
4	.660+01	.2805+02	-.9689-03	.1072-04	.1000-02	.2505-01
5	.102+02	.6447+02	-.2298-02	.3784-04	.2000-02	.3026-01
6	.162+02	.1585+01	-.5686-02	.1387-03	.5000-02	.6307-01
7	.222+02	.3233+01	-.1023-01	.3062-03	.1300-01	.8306-01
8	.282+02	.5363+01	-.1575-01	.5382-03	.2400-01	.3055+00
9	.342+02	.7045+01	-.2201-01	.8211-03	.3800-01	.1288+00
10	.402+02	.1055+00	-.2877-01	.1136-02	.5500-01	.1478+00
11	.462+02	.1428+00	-.3597-01	.1477-02	.7400-01	.1680+00
12	.522+02	.1775+00	-.4383-01	.1967-02	.9300-01	.1903+00
13	.582+02	.2144+00	-.5210-01	.2285-02	.1130+00	.2120+00
14	.642+02	.2528+00	-.6096-01	.2748-02	.1330+00	.2302+00
15	.702+02	.2930+00	-.6985-01	.3201-02	.1550+00	.2564+00
16	.762+02	.3321+00	-.8098-01	.3674-02	.1710+00	.2802+00
17	.822+02	.3745+00	-.9158-01	.4140-02	.1910+00	.3037+00
18	.882+02	.4180+00	-.1024+00	.5096-02	.2120+00	.3275+00

Q ADD UN0606

## SUMMARY OF TEST NO. 000606

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MATERIAL DATA

MATERIAL IS AIR 3335-1

RULK MODULUS = 5000x106

VOLUMETRIC EXPANSION COEFFICIENT = .1800-n3

TYPE ... INITIAL

INITIAL STRAIN RATE = 2.6700x10<sup>-2</sup>

PRESSURE = 0. PSIA

TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. °F	ε11	STRAINS (CALCULATED) ε22	ε12	TIME STRESS (S11 - S22)
1	.000	0.	.000	.000	.000	.000
2	.000x10	0.	.6722-02	-.3328-02	.000	.000x10
3	.180x10	0.	.2030-01	-.8872-02	.000	.420x10
4	.480x10	0.	.5504-01	-.2306-01	.000	.1272x10
5	.690x10	0.	.8002-01	-.3305-01	.000	.1648x10
6	.720x10	0.	.8002-01	-.3345-01	.000	.1343x10
7	.750x10	0.	.8002-01	-.3345-01	.000	.1074x10
8	.840x10	0.	.8002-01	-.3345-01	.000	.0562x10
9	.960x10	0.	.8002-01	-.3345-01	.000	.0165x10
10	.114x10	0.	.8002-01	-.3305-01	.000	.710x10
11	.144x10	0.	.8002-01	-.3345-01	.000	.621x10
12	.224x10	0.	.8002-01	-.3208-01	.000	.5047x10
13	.234x10	0.	.8726-01	-.3541-01	.000	.1058x10
14	.245x10	0.	.1019x00	-.4017-01	.000	.1617x10
15	.258x10	0.	.1167x00	-.4437-01	.000	.1800x10
16	.280x10	0.	.1544x00	-.5334-01	.000	.2220x10
17	.314x10	0.	.1833x00	-.6010-01	.000	.2372x10
18	.340x10	0.	.2333x00	-.6567-01	.000	.2488x10
19	.394x10	0.	.2971x00	-.7103-01	.000	.2520x10
20	.396x10	0.	.2971x00	-.7103-01	.000	.2367x10
21	.402x10	0.	.2971x00	-.7173-01	.000	.1983x10
22	.414x10	0.	.2971x00	-.7153-01	.000	.1651x10
23	.434x10	0.	.2971x00	-.7133-01	.000	.1393x10
24	.469x10	0.	.2971x00	-.7114-01	.000	.1215x10
25	.504x10	0.	.2971x00	-.7114-01	.000	.1108x10
26	.564x10	0.	.2971x00	-.7094-01	.000	.0987x10
27	.684x10	0.	.2971x00	-.7074-01	.000	.0732x10
28	.958x10	0.	.2971x00	-.7054-01	.000	.7638x10
29	.912x10	0.	.3631x00	-.7005-01	.000	.6064x10
30	.924x10	0.	.3201x00	-.7200-01	.000	.1531x10
31	.936x10	0.	.3374x00	-.7462-01	.000	.1980x10
32	.948x10	0.	.3548x00	-.7502-01	.000	.2222x10
33	.960x10	0.	.3724x00	-.7710-01	.000	.1775x10
34	.978x10	0.	.3092x00	-.7905-01	.000	.2512x10
35	.101x10	0.	.4447x00	-.8204-01	.000	.2588x10
36	.104x10	0.	.4013x00	-.8417-01	.000	.2602x10
37	.107x10	0.	.5390x00	-.8620-01	.000	.2574x10
38	.110x10	0.	.5879x00	-.8882-01	.000	.2514x10
39	.113x10	0.	.6378x00	-.9166-01	.000	.2433x10
40	.115x10	0.	.6684x00	-.9441-01	.000	.2387x10

## MATERIAL DATA

MATERIAL IS AIR 3335-1

BULK MODULUS = -5000+06

VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

## TEST DATA

TYPE ... INITIAL

INITIAL STRAIN RATE = .5700+00

PRESSURE = % PSIG

TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	T1	STRAIN INVARIANTS I2	I3	CORRECTED DILATATION	OCTAHEDRAL STRAIN
1	.000	.0000	.0000	.0000	.0000	.0000
2	.600+00	.6763-04	-.3367-04	.7444-07	.6722-08	.8718-02
3	.180+01	.9509-02	-.2915-03	.1598-05	.2000-02	.1375-01
4	.430+01	.8009-02	-.2007-02	.2928-04	.5000-02	.3682-01
5	.590+01	.1312-01	-.4234-02	.8052-04	.5000-02	.5400-01
6	.720+01	.1312-01	-.4234-02	.8052-04	.5000-02	.5400-01
7	.780+01	.1312-01	-.4234-02	.8052-04	.5000-02	.5400-01
8	.840+01	.1312-01	-.4234-02	.8052-04	.5000-02	.5400-01
9	.960+01	.1312-01	-.4234-02	.8052-04	.5000-02	.5400-01
10	.114+02	.1312-01	-.4234-02	.8052-04	.5000-02	.5400-01
11	.144+02	.1312-01	-.4234-02	.8052-04	.5000-02	.5400-01
12	.228+02	.1405-01	-.4191-02	.8705-04	.6000-02	.5327-01
13	.234+02	.1644-01	-.4026-02	.1054-03	.7000-02	.5781-01
14	.246+02	.2152-01	-.6571-02	.1544-03	.9000-02	.6606-01
15	.258+02	.2762-01	-.8384-02	.2297-03	.1200-01	.7501-01
16	.268+02	.4774-01	-.1363-01	.4394-03	.2200-01	.9704-01
17	.318+02	.7310-01	-.2633-01	.6083-03	.3600-01	.1195+00
18	.348+02	.1020+00	-.2633-01	.1006-02	.5200-01	.1400+00
19	.394+02	.1533+00	-.3757-01	.1537-02	.8100-01	.1740+00
20	.396+02	.1533+00	-.3757-01	.1537-02	.8100-01	.1740+00
21	.402+02	.1537+00	-.3748-01	.1529-02	.8150-01	.1736+00
22	.414+02	.1541+00	-.3739-01	.1520-02	.8200-01	.1738+00
23	.433+02	.1545+00	-.3730-01	.1512-02	.8250-01	.1737+00
24	.468+02	.1540+00	-.3721-01	.1504-02	.8300-01	.1736+00
25	.504+02	.1540+00	-.3721-01	.1504-02	.8300-01	.1736+00
26	.564+02	.1553+00	-.3712-01	.1495-02	.8350-01	.1735+00
27	.604+02	.1556+00	-.3703-01	.1487-02	.8400-01	.1734+00
28	.908+02	.1561+00	-.3694-01	.1470-02	.8450-01	.1733+00
29	.912+02	.1612+00	-.3697-01	.1426-02	.8750-01	.1733+00
30	.924+02	.1743+00	-.4136-01	.1701-02	.9400-01	.1953+00
31	.936+02	.1882+00	-.4478-01	.1878-02	.1010+00	.1962+00
32	.949+02	.2030+00	-.4811-01	.2045-02	.1090+00	.2031+00
33	.960+02	.2180+00	-.5154-01	.2219-02	.1170+00	.2120+00
34	.978+02	.2411+00	-.5686-01	.2495-02	.1290+00	.2254+00
35	.101+03	.2806+00	-.6623-01	.3003-02	.1490+00	.2483+00
36	.104+03	.229+00	-.7562-01	.3481-02	.1710+00	.2713+00
37	.107+03	.3666+00	-.8550-01	.4005-02	.1930+00	.2947+00
38	.110+03	.4102+00	-.9654-01	.4638-02	.2130+00	.3190+00
39	.113+03	.4545+00	-.1085+00	.5358-02	.2320+00	.3436+00
40	.115+03	.4795+00	-.1173+00	.5957-02	.2400+00	.3506+00

# SUMMARY OF TEST NO. 000607

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## MATERIAL DATA

MATERIAL IS ABR 3335-1  
BULK MODULUS = .5000+06  
VOLUME FRICTION COEFFICIENT = .1800-03

TYPE ... INITIAL  
INITIAL STRAIN RATE = .2700+00  
PRESSURE = 0. PSTC  
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG. F	F11	F22	STRAINS (CALCULATED)	F12	TOLF STRESS (S11 - S22)
1	.000	0.	.0000	.0000	.0000	.0000	.0000
2	.000+00	0.	.4020+02	-.2002-02	-.2002-02	.0000	.1807+02
3	.000+00	0.	.1078-01	-.5303-02	-.5303-02	.0000	.942+02
4	.275+01	0.	.3129-01	-.1405-01	-.1405-01	.0000	.914+02
5	.576+01	0.	.6630-01	-.2920-01	-.2920-01	.0000	.1804+03
6	.076+01	0.	.102+00	-.4176-01	-.4176-01	.0000	.1825+03
7	.118+02	0.	.1700+00	-.5141-01	-.5141-01	.0000	.2080+03
8	.148+02	0.	.1784+00	-.5273-01	-.5273-01	.0000	.2229+03
9	.172+02	0.	.2130+00	-.6507-01	-.6507-01	.0000	.231+03
10	.211+02	0.	.2637+00	-.7114-01	-.7114-01	.0000	.2377+03
11	.214+02	0.	.2603+00	-.7041-01	-.7041-01	.0000	.2410+03
12	.220+02	0.	.2621+00	-.6800-01	-.6800-01	.0000	.2517+03
13	.232+02	0.	.2350+00	-.6721-01	-.6721-01	.0000	.2221+02
14	.240+02	0.	.2306+00	-.6406-01	-.6406-01	.0000	.5046+02
15	.262+02	0.	.1057+00	-.6043-01	-.6043-01	.0000	.244+02
16	.263+02	0.	.1057+00	-.5238-01	-.5238-01	.0000	.284+02
17	.270+02	0.	.1180+00	-.4317-01	-.4317-01	.0000	.234+01
18	.280+02	0.	.1180+00	-.4317-01	-.4317-01	.0000	.231+01
19	.280+02	0.	.1180+00	-.4317-01	-.4317-01	.0000	.232+02
20	.280+02	0.	.1180+00	-.4331-01	-.4331-01	.0000	.235+02
21	.300+02	0.	.1180+00	-.4300-01	-.4300-01	.0000	.1725+03
22	.300+02	0.	.1180+00	-.4300-01	-.4300-01	.0000	.1082+02
23	.300+02	0.	.1180+00	-.4300-01	-.4300-01	.0000	.1082+02
24	.300+02	0.	.1180+00	-.4300-01	-.4300-01	.0000	.288+02
25	.300+02	0.	.1180+00	-.4300-01	-.4300-01	.0000	.256+02
26	.300+02	0.	.1180+00	-.4300-01	-.4300-01	.0000	.288+02
27	.300+02	0.	.1180+00	-.4300-01	-.4300-01	.0000	.288+02
28	.300+02	0.	.1180+00	-.4300-01	-.4300-01	.0000	.111+02
29	.300+02	0.	.1180+00	-.4300-01	-.4300-01	.0000	.111+02
30	.300+02	0.	.1180+00	-.4300-01	-.4300-01	.0000	.215+03
31	.300+02	0.	.1180+00	-.4300-01	-.4300-01	.0000	.288+02
32	.300+02	0.	.1180+00	-.4300-01	-.4300-01	.0000	.288+02
33	.300+02	0.	.1180+00	-.4300-01	-.4300-01	.0000	.251+03
34	.300+02	0.	.1180+00	-.4300-01	-.4300-01	.0000	.256+03
35	.300+02	0.	.1180+00	-.4300-01	-.4300-01	.0000	.250+03
36	.300+02	0.	.1180+00	-.4300-01	-.4300-01	.0000	.250+03
37	.300+02	0.	.1180+00	-.4300-01	-.4300-01	.0000	.2447+03

## MATERIAL DATA

MATERIAL IS AL-9 3335-1

BULK MODULUS = 5000+06

VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

## TEST DATA

TYPE ... UNIAXIAL

INITIAL STRAIN RATE = .8700+00

PRESSURE = 0. PSIE

TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	STRAIN INVARIANTS I1	I2	I3	CORRECTED DILATATION	CCTAUEFFICAL STRAIN
1	.000	.000	.000	.000	.000	.000
2	.360+00	.2417-04	-.1212-04	.1614-07	.4028-08	.2843-02
3	.660+00	.1712-03	-.0619-04	.3031-06	.3078-07	.2680-02
4	.276+01	.1306-02	-.7122-03	.6994-05	.2129-07	.2140-01
5	.576+01	.7035-02	-.0030-02	.5690-04	.2000-02	.4910-01
6	.076+01	.1088-01	-.6777-02	.1756-03	.7000-02	.6787-01
7	.118+02	.3712-01	-.1175-01	.7690-03	.1500-01	.0020-01
8	.148+02	.6064-01	-.1751-01	.6153-03	.2800-01	.1118+00
9	.178+02	.8754-01	-.2418-01	.9274-03	.4200-01	.1355+00
10	.211+02	.1214+00	-.2245-01	.1334-02	.6000-01	.1578+00
11	.214+02	.1105+00	-.3170-01	.1291-02	.5050-01	.1550+00
12	.220+02	.1131+00	-.3021-01	.1217-02	.5600-01	.1516+00
13	.232+02	.1013+00	-.2717-01	.1065-02	.5000-01	.1428+00
14	.244+02	.0067-01	-.2415-01	.9124-03	.4500-01	.1335+00
15	.262+02	.7402-01	-.2000-01	.7146-03	.3700-01	.1207+00
16	.292+02	.5167-01	-.1367-01	.4300-03	.2600-01	.0957-01
17	.322+02	.3045-01	-.8002-02	.2216-03	.1650-01	.7640-01
18	.329+02	.3255-01	-.8402-02	.2215-03	.1650-01	.7680-01
19	.340+02	.3255-01	-.8402-02	.2216-03	.1650-01	.7640-01
20	.358+02	.3228-01	-.8422-02	.2230-03	.1620-01	.7646-01
21	.365+02	.3210-01	-.8036-02	.2239-03	.1600-01	.7650-01
22	.449+02	.3210-01	-.8036-02	.2239-03	.1600-01	.7650-01
23	.779+02	.3121-01	-.8503-02	.2286-03	.1500-01	.7672-01
24	.744+02	.3439-01	-.9125-02	.2498-03	.1700-01	.7666-01
25	.790+02	.3826-01	-.1011-01	.2860-03	.1900-01	.8006-01
26	.808+02	.5124-01	-.1327-01	.4111-03	.2600-01	.8712-01
27	.838+02	.7480-01	-.1040-01	.6787-03	.3000-01	.1101+00
28	.868+02	.1016+00	-.2640-01	.1012-02	.5150-01	.1410+00
29	.898+02	.1286+00	-.3472-01	.1460-02	.6300-01	.1638+00
30	.928+02	.1610+00	-.4326-01	.1921-02	.7900-01	.1960+00
31	.958+02	.1957+00	-.5243-01	.2431-02	.9600-01	.2085+00
32	.988+02	.2328+00	-.6212-01	.2985-02	.1180+00	.2312+00
33	.102+03	.2721+00	-.7226-01	.3571-02	.1330+00	.2542+00
34	.105+03	.3128+00	-.8104-01	.4214-02	.1520+00	.2777+00
35	.108+03	.3556+00	-.9414-01	.4877-02	.1720+00	.3014+00
36	.111+03	.3990+00	-.1062+00	.5630-02	.1910+00	.3258+00
37	.113+03	.4262+00	-.1135+00	.6085-02	.2030+00	.3406+00

# SUMMARY OF TEST RESULTS

MATERIAL: 304L

ROCKWELL C: 30

VOLUME EXPANSION COEFFICIENT = 18.10-03

INITIAL GRAIN SIZE: 6-8  
PRESSURE: 6 PSI  
TEMPERATURE: 1000 F

DATA POINT	TIME (SEC)	TEMP (F)	STRESS (PSI)	STRAIN (IN/IN)	YIELD STRESS (PSI)
1	0.00	0.	0.00	0.00	0.00
2	0.00	0.	0.00	0.00	0.00
3	0.00	0.	0.00	0.00	0.00
4	0.00	0.	0.00	0.00	0.00
5	0.00	0.	0.00	0.00	0.00
6	0.00	0.	0.00	0.00	0.00
7	0.00	0.	0.00	0.00	0.00
8	0.00	0.	0.00	0.00	0.00
9	0.00	0.	0.00	0.00	0.00
10	0.00	0.	0.00	0.00	0.00
11	0.00	0.	0.00	0.00	0.00
12	0.00	0.	0.00	0.00	0.00
13	0.00	0.	0.00	0.00	0.00
14	0.00	0.	0.00	0.00	0.00
15	0.00	0.	0.00	0.00	0.00
16	0.00	0.	0.00	0.00	0.00
17	0.00	0.	0.00	0.00	0.00
18	0.00	0.	0.00	0.00	0.00
19	0.00	0.	0.00	0.00	0.00
20	0.00	0.	0.00	0.00	0.00
21	0.00	0.	0.00	0.00	0.00
22	0.00	0.	0.00	0.00	0.00
23	0.00	0.	0.00	0.00	0.00
24	0.00	0.	0.00	0.00	0.00
25	0.00	0.	0.00	0.00	0.00
26	0.00	0.	0.00	0.00	0.00
27	0.00	0.	0.00	0.00	0.00
28	0.00	0.	0.00	0.00	0.00
29	0.00	0.	0.00	0.00	0.00
30	0.00	0.	0.00	0.00	0.00
31	0.00	0.	0.00	0.00	0.00
32	0.00	0.	0.00	0.00	0.00
33	0.00	0.	0.00	0.00	0.00
34	0.00	0.	0.00	0.00	0.00
35	0.00	0.	0.00	0.00	0.00
36	0.00	0.	0.00	0.00	0.00
37	0.00	0.	0.00	0.00	0.00

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## MATERIAL DATA

MATERIAL IS AMR 3335-1  
 BULK MODULUS = .5000+06  
 VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

## TEST DATA

TYPE ... UNIAXIAL  
 INITIAL STRAIN RATE = .4700+00  
 PRESSURE = 0. PSIG  
 TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	STRAIN INVAIANTS I1	I2	I3	CORRECTED DILATATION	OCTAHEDRAL STRAIN
1	.000	.0000	.0000	.0000	.0000	.0000
2	.600+00	.6703-04	-.3767-04	.7444-07	.6722-08	.8738-02
3	.140+01	.5981-03	-.5030-03	.1071-05	.2030-07	.1421-01
4	.440+01	.5507-02	-.2110-02	.3364-04	.1500-02	.3760-01
5	.700+01	.1537-01	-.5439-02	.1206-03	.5000-02	.6065-01
6	.102+02	.3185-01	-.9473-02	.2047-03	.1300-01	.8201-01
7	.138+02	.5368-01	-.1549-01	.5232-03	.2450-01	.1047+00
8	.154+02	.6760-01	-.1877-01	.6668-03	.3220-01	.3163+00
9	.156+02	.6767-01	-.1876-01	.6659-03	.3230-01	.3163+00
10	.162+02	.6776-01	-.1875-01	.6640-03	.3240-01	.3163+00
11	.168+02	.6784-01	-.1874-01	.6640-03	.3250-01	.3163+00
12	.170+02	.6793-01	-.1873-01	.6630-03	.3260-01	.3163+00
13	.173+02	.6827-01	-.1868-01	.6502-03	.3300-01	.3161+00
14	.225+02	.6853-01	-.1865-01	.6564-03	.3330-01	.3161+00
15	.208+02	.6870-01	-.1863-01	.6545-03	.3350-01	.3160+00
16	.408+02	.6870-01	-.1863-01	.6545-03	.3350-01	.3160+00
17	.534+02	.6827-01	-.1868-01	.6502-03	.3300-01	.3161+00
18	.540+02	.7360-01	-.1995-01	.7158-03	.3600-01	.3204+00
19	.552+02	.8347-01	-.2278-01	.8541-03	.4050-01	.3204+00
20	.504+02	.9523-01	-.2553-01	.9824-03	.4700-01	.3390+00
21	.576+02	.1122+00	-.2754-01	.1041-02	.5050-01	.3854+00
22	.606+02	.1447+00	-.3488-01	.1390-02	.7750-01	.3671+00
23	.643+02	.1802+00	-.4478-01	.1878-02	.1010+00	.3942+00
24	.648+02	.1882+00	-.4478-01	.1878-02	.1010+00	.3942+00
25	.660+02	.1880+00	-.4472-01	.1873-02	.1013+00	.3942+00
26	.672+02	.1885+00	-.4468-01	.1860-02	.1015+00	.3941+00
27	.696+02	.1868+00	-.4462-01	.1863-02	.1018+00	.3941+00
28	.746+02	.1880+00	-.4458-01	.1850-02	.1020+00	.3940+00
29	.743+02	.1880+00	-.4458-01	.1850-02	.1020+00	.3940+00
30	.948+02	.1951+00	-.4503-01	.1818-02	.1055+00	.3975+00
31	.960+02	.2092+00	-.4040-01	.2107-02	.1125+00	.2665+00
32	.979+02	.2320+00	-.5664-01	.2377-02	.1245+00	.2200+00
33	.996+02	.2550+00	-.6022-01	.2673-02	.1360+00	.2337+00
34	.103+03	.2954+00	-.6967-01	.3176-02	.1565+00	.2566+00
35	.106+03	.3375+00	-.7054-01	.3709-02	.1775+00	.2700+00
36	.109+03	.3806+00	-.9012-01	.4301-02	.1980+00	.3038+00
37	.112+03	.4241+00	-.1018+00	.4995-02	.2170+00	.3923+00

Q AND U00600

## SUMMARY OF TEST NO. 1110600

## MATERIAL DATA

MATERIAL IS ANR 3335-1  
 BULK MODULUS = .5000+06  
 VOLUMETRIC EXPANSION COEFFICIENT = .1000-03

## TEST DATA

TYPE ... UNIAxIAL  
 INITIAL STRAIN RATE = .6700+00  
 PRESSURE = 50. PSIA  
 TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	F11	F22	STRAINS (CALCULATED) E33	E12	TRIF STRESS (C11 - C22)
1	.000	0.	.1333-04	-.3333-04	-.3333-04	.0000	.0000
2	.120+01	0.	.1346-01	-.6645-02	-.6645-02	.0000	.8466+02
3	.240+01	0.	.2712-01	-.1308-01	-.1308-01	.0000	.7701+02
4	.420+01	0.	.4796-01	-.2195-01	-.2195-01	.0000	.1372+03
5	.720+01	0.	.8360-01	-.3562-01	-.3562-01	.0000	.1768+03
6	.102+02	0.	.1203+00	-.4712-01	-.4712-01	.0000	.2220+03
7	.132+02	0.	.1582+00	-.5508-01	-.5508-01	.0000	.2410+03
8	.162+02	0.	.1972+00	-.6320-01	-.6320-01	.0000	.2616+03
9	.192+02	0.	.2373+00	-.6936-01	-.6936-01	.0000	.2731+03
10	.222+02	0.	.2786+00	-.7451-01	-.7451-01	.0000	.2767+03
11	.252+02	0.	.3210+00	-.7920-01	-.7920-01	.0000	.2853+03
12	.282+02	0.	.3644+00	-.8327-01	-.8327-01	.0000	.2901+03
13	.312+02	0.	.4090+00	-.8694-01	-.8694-01	.0000	.2926+03
14	.342+02	0.	.4540+00	-.9045-01	-.9045-01	.0000	.2935+03
15	.372+02	0.	.5016+00	-.9413-01	-.9413-01	.0000	.2905+03
16	.402+02	0.	.5496+00	-.1004+00	-.1004+00	.0000	.2866+03

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## MATERIAL DATA

MATERIAL IS ANR 3335-1  
 HULK ACUOLUS = .5000+06  
 VOLUMETRIC EXPANSION-COEFFICIENT = .1800-03

## TEST DATA

TYPE ... UNIAxIAL  
 INITIAL STRAIN RATE = .6700+00  
 PRESSURE = 50. PSTG  
 TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	STRAIN INVARIANTS			CORRECTED DILATATION	OCTAHEDRAL STRAIN
		I1	I2	I3		
1	.000	-.1000-03	.3333-08	-.3704-13	-.1000-03	.0000
2	.1204+01	.1670-03	-.1347-03	.5041-06	-.0000-04	.0075-02
3	.2404+01	.0506-03	-.5306-03	.4043-05	-.0007-04	.1000-01
4	.4204+01	.4056-02	-.1624-02	.2312-04	.0000-03	.3000-01
5	.7204+01	.1235-01	-.4607-02	.1061-03	.0000-02	.5000-01
6	.1024+02	.2611-01	-.0121-02	.2672-03	.0000-02	.7004-01
7	.1324+02	.4626-01	-.1458-01	.4050-03	.1000-01	.1010+00
8	.1624+02	.7015-01	-.2006-01	.7099-03	.3140-01	.1220+00
9	.1924+02	.0062-01	-.2011-01	.1142-02	.4000-01	.1000-01
10	.2224+02	.1256+00	-.3506-01	.1547-02	.6100-01	.1000-01
11	.2524+02	.1626+00	-.4057-01	.2013-02	.7000-01	.1000-01
12	.2824+02	.1970+00	-.5376-01	.2527-02	.8000-01	.2110+00
13	.3124+02	.2352+00	-.6357-01	.3002-02	.1130+00	.2330+00
14	.3424+02	.2730+00	-.7008-01	.3720-02	.1310+00	.2570+00
15	.3724+02	.3134+00	-.8558-01	.4445-02	.1400+00	.2800+00
16	.4024+02	.3468+00	-.1003+00	.5541-02	.1570+00	.3060+00

END 010600

## SUMMARY OF TEST NO. UI0601

## MATERIAL DATA

MATERIAL IS ABR 3335-1

BULK MODULUS = 5000+06

VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

## TEST DATA

TYPE ... INITIAL

INITIAL STRAIN RATE = .6700+00

PRESSURE = 100. PSI

TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG. C	F11	F22	STRAINS (CALCULATED) E33	E12	TOLF STRESS (E11 - E22)
1	.000	0.	.666-04	-.666-04	-.666-04	.0000	.0000
2	.000+00	0.	.665-02	-.3104-02	-.3304-02	.0000	.0000
3	.100+01	0.	.2023-01	-.9018-02	-.9018-02	.0000	.0000
4	.300+01	0.	.3309-01	-.1608-01	-.1608-01	.0000	.0000
5	.600+01	0.	.6017-01	-.3052-01	-.3052-01	.0000	.0000
6	.900+01	0.	.1055+00	-.4323-01	-.4323-01	.0000	.0000
7	.943+01	0.	.1158+00	-.4650-01	-.4650-01	.0000	.0000
8	.102+02	0.	.1158+00	-.4650-01	-.4650-01	.0000	.0000
9	.103+02	0.	.1158+00	-.4664-01	-.4664-01	.0000	.0000
10	.120+02	0.	.1158+00	-.4673-01	-.4673-01	.0000	.0000
11	.138+02	0.	.1158+00	-.4677-01	-.4677-01	.0000	.0000
12	.155+02	0.	.1158+00	-.4682-01	-.4682-01	.0000	.0000
13	.210+02	0.	.1158+00	-.4686-01	-.4686-01	.0000	.0000
14	.270+02	0.	.1158+00	-.4686-01	-.4686-01	.0000	.0000
15	.278+02	0.	.1233+00	-.4913-01	-.4913-01	.0000	.0000
16	.284+02	0.	.1384+00	-.5324-01	-.5324-01	.0000	.0000
17	.300+02	0.	.1536+00	-.5730-01	-.5730-01	.0000	.0000
18	.313+02	0.	.1768+00	-.6280-01	-.6280-01	.0000	.0000
19	.335+02	0.	.2004+00	-.6700-01	-.6700-01	.0000	.0000
20	.360+02	0.	.2324+00	-.7354-01	-.7354-01	.0000	.0000
21	.390+02	0.	.2735+00	-.7980-01	-.7980-01	.0000	.0000
22	.420+02	0.	.3158+00	-.8538-01	-.8538-01	.0000	.0000
23	.420+02	0.	.3158+00	-.8554-01	-.8554-01	.0000	.0000
24	.430+02	0.	.3158+00	-.8632-01	-.8632-01	.0000	.0000
25	.460+02	0.	.3158+00	-.8632-01	-.8632-01	.0000	.0000
26	.463+02	0.	.3158+00	-.8663-01	-.8663-01	.0000	.0000
27	.492+02	0.	.3158+00	-.8683-01	-.8683-01	.0000	.0000
28	.552+02	0.	.3158+00	-.8749-01	-.8749-01	.0000	.0000
29	.750+02	0.	.3158+00	-.8828-01	-.8828-01	.0000	.0000
30	.762+02	0.	.3200+00	-.8850-01	-.8850-01	.0000	.0000
31	.774+02	0.	.3200+00	-.8874-01	-.8874-01	.0000	.0000
32	.786+02	0.	.3556+00	-.9200-01	-.9200-01	.0000	.0000
33	.790+02	0.	.3732+00	-.9373-01	-.9373-01	.0000	.0000
34	.810+02	0.	.4010+00	-.9517-01	-.9517-01	.0000	.0000
35	.820+02	0.	.4101+00	-.9524-01	-.9524-01	.0000	.0000
36	.840+02	0.	.4545+00	-.9524-01	-.9524-01	.0000	.0000
37	.870+02	0.	.4631+00	-.9524-01	-.9524-01	.0000	.0000
38	.116+02	0.	.4631+00	-.9524-01	-.9524-01	.0000	.0000
39	.120+02	0.	.4631+00	-.9524-01	-.9524-01	.0000	.0000

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## MATERIAL DATA

MATERIAL IS 409 3335-1  
 BULK MODULUS = .5000+06  
 VOLUMETRIC EXPANSION COEFFICIENT = .0000-03

## TEST DATA

TYPE ... UNIAxIAL  
 INITIAL STRAIN RATE = .0700+00  
 PRESSURE = 100. PSIG  
 TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	I1	STRAIN INVARIANTS I2	I3	CORRECTED DILATATION	OCTAHEDRAL STRAIN
1	.000	-.2000-03	-.1333-07	-.2963-12	-.2000-03	.1054+07
2	.600+00	-.1330-03	-.1366-04	.7667-07	-.2000-03	.4757-02
3	.180+01	.3981-03	-.3030-03	.1990-05	-.2000-03	.1431-01
4	.300+01	.1834-03	-.2346-03	.8768-05	.2000-03	.2560-01
5	.600+01	.8126-02	-.3091-02	.6445-04	.1000-02	.4700-01
6	.900+01	.1903-01	-.7050-02	.1971-03	.5000-02	.7010-01
7	.084+01	.2284-01	-.8611-02	.2505-03	.6000-02	.7653-01
8	.102+02	.2214-01	-.8611-02	.2505-03	.6000-02	.7653-01
9	.102+02	.2257-01	-.8630-02	.2510-03	.6000-02	.7653-01
10	.120+02	.2230-01	-.8642-02	.2520-03	.6000-02	.7653-01
11	.130+02	.2230-01	-.8649-02	.2534-03	.6000-02	.7666-01
12	.150+02	.2221-01	-.8655-02	.2549-03	.5000-02	.7666-01
13	.210+02	.2212-01	-.8661-02	.2544-03	.5000-02	.7670-01
14	.270+02	.2212-01	-.8661-02	.2544-03	.5000-02	.7670-01
15	.276+02	.2504-01	-.8702-02	.2576-03	.6000-02	.6000-02
16	.230+02	.3187-01	-.1190-01	.3022-03	.6000-02	.6000-02
17	.300+02	.3000-01	-.1432-01	.5042-03	.1330-01	.6001-01
18	.314+02	.5110-01	-.1826-01	.6070-03	.1730-01	.1190-01
19	.336+02	.6456-01	-.2260-01	.9236-03	.2280-01	.1265+00
20	.368+02	.8535-01	-.2878-01	.1257-02	.3230-01	.1402+00
21	.300+02	.1130+00	-.3729-01	.1742-02	.4530-01	.1466+00
22	.420+02	.1450+00	-.4663-01	.2302-02	.5020-01	.1051+00
23	.426+02	.1447+00	-.4670-01	.2310-02	.5080-01	.1052+00
24	.430+02	.1430+00	-.4684-01	.2331-02	.5700-01	.1054+00
25	.450+02	.1431+00	-.4706-01	.2352-02	.5680-01	.1055+00
26	.469+02	.1255+00	-.4721-01	.2370-02	.5600-01	.1057+00
27	.472+02	.1211+00	-.4730-01	.2381-02	.5550-01	.1058+00
28	.495+02	.1400+00	-.4760-01	.2417-02	.5380-01	.1051+00
29	.750+02	.1392+00	-.4796-01	.2461-02	.5180-01	.1051+00
30	.762+02	.1437+00	-.4801-01	.2519-02	.5430-01	.1050+00
31	.774+02	.1775+00	-.5294-01	.2760-02	.6000-01	.2020+00
32	.786+02	.1715+00	-.5700-01	.3013-02	.6730-01	.2110+00
33	.793+02	.1858+00	-.6118-01	.3270-02	.7380-01	.2201+00
34	.810+02	.1900+00	-.6560-01	.3571-02	.7080-01	.2209+00
35	.829+02	.2216+00	-.7240-01	.4035-02	.8880-01	.2434+00
36	.846+02	.2433+00	-.7668-01	.4530-02	.9780-01	.2575+00
37	.876+02	.2800+00	-.9315-01	.5537-02	.1098+00	.2620+00
38	.906+02	.3191+00	-.1070+00	.6576-02	.1238+00	.3065+00
39	.936+02	.3588+00	-.1322+00	.7783-02	.1363+00	.3317+00

## MATERIAL DATA

MATERIAL IS ANR 3335-1  
 RULY BODULUS = .5000406  
 VOLUME TRIC EXPANSION COEFFICIENT = .1800-03

## TEST DATA

TYPE ... INITIALIAL  
 INITIAL STRAIN RATE = .6700+00  
 PRESSURE = 100. PSIG  
 TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	F11	F22	STRAINS (CALCULATED) E33	E12	TRIP STRESS (S11 - S22)
1	.000	0.	-.6668-04	-.6666-04	-.6664-04	.0000	.0000
2	.360+00	0.	.3061-02	-.2069-02	-.2068-02	.0000	.1707+02
3	.156+01	0.	.1750-01	-.8627-02	-.8627-02	.0000	.5566+02
4	.270+01	0.	.3123-01	-.1501-01	-.1501-01	.0000	.8564+02
5	.16+01	0.	.5021-01	-.2683-01	-.2683-01	.0000	.1365+03
6	.16+01	0.	.9520-01	-.3909-01	-.3909-01	.0000	.1003+03
7	.112+02	0.	.1323+02	-.5147-01	-.5147-01	.0000	.2630+03
8	.142+02	0.	.1705+00	-.6009-01	-.6009-01	.0000	.2600+03
9	.172+02	0.	.2000+00	-.6013-01	-.6013-01	.0000	.2801+03
10	.202+02	0.	.2504+00	-.7602-01	-.7602-01	.0000	.3005+03
11	.232+02	0.	.2920+00	-.8214-01	-.8214-01	.0000	.3005+03
12	.262+02	0.	.3347+00	-.8704-01	-.8704-01	.0000	.3100+03
13	.291+02	0.	.3261+00	-.8735-01	-.8735-01	.0000	.3150+03
14	.380+02	0.	.3080+00	-.8654-01	-.8654-01	.0000	.3150+03
15	.392+02	0.	.2920+00	-.8402-01	-.8402-01	.0000	.3126+03
16	.392+02	0.	.2504+00	-.8010-01	-.8010-01	.0000	.3126+03
17	.376+02	0.	.1783+00	-.6652-01	-.6652-01	.0000	.2702+02
18	.400+02	0.	.1475+00	-.5004-01	-.5004-01	.0000	.1176+02
19	.406+02	0.	.1551+00	-.6107-01	-.6107-01	.0000	.1176+02
20	.418+02	0.	.1705+00	-.6087-01	-.6087-01	.0000	.1176+02
21	.442+02	0.	.2019+00	-.7218-01	-.7218-01	.0000	.1176+02
22	.472+02	0.	.2019+00	-.7004-01	-.7004-01	.0000	.1176+02
23	.502+02	0.	.2836+00	-.8549-01	-.8549-01	.0000	.1176+02
24	.532+02	0.	.3261+00	-.9046-01	-.9046-01	.0000	.1176+02
25	.562+02	0.	.3697+00	-.9518-01	-.9518-01	.0000	.1176+02
26	.592+02	0.	.4104+00	-.9964-01	-.9964-01	.0000	.1176+02
27	.622+02	0.	.4603+00	-.1043+00	-.1043+00	.0000	.1176+02
28	.652+02	0.	.5073+00	-.1000+00	-.1000+00	.0000	.1176+02
29	.682+02	0.	.5554+00	-.1116+00	-.1116+00	.0000	.1176+02
30	.700+02	0.	.5848+00	-.1168+00	-.1168+00	.0000	.1176+02

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## MATERIAL DATA

MATERIAL IS AIR 3335-1

BULK MODULUS = .5000+06

VOLUMETRIC EXPANSION COEFFICIENT = .1800+03

## TEST DATA

TYPE ... INITIAL

INITIAL STRAIN RATE = .6700+00

PRESSURE = 100. PSIG

TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	STRAIN INVARIANTS			CORRECTED DILATATION	OCTAHEDRAL STRAIN
		I1	I2	I3		
1	.000	-.2000-03	.1333-07	-.2063-12	-.2000-03	.1054-07
2	.360+00	-.1758+03	-.1211-04	.1685-07	-.2000-03	.2842-02
3	.150+01	-.2500-03	-.2276-03	.1303-05	-.2000-03	.1232-01
4	.276+01	.1106-02	-.7123-03	.7040-05	-.2000-03	.2180-01
5	.516+01	.5545-02	-.2457-02	.4263-04	.8001-03	.8056-01
6	.416+01	.1523-01	-.6014-02	.1522-03	.3000-02	.6373-01
7	.112+02	.2930-01	-.1097-01	.3506-03	.8000-02	.8663-01
8	.142+02	.4857-01	-.1708-01	.6343-03	.1400-01	.1001+00
9	.172+02	.7162-11	-.2424-01	.1003-02	.2600-01	.1315+00
10	.202+02	.0834-01	-.3229-01	.1447-02	.3000-01	.1530+00
11	.232+02	.1277+00	-.4122-01	.1070-02	.5180-01	.1764+00
12	.262+02	.1588+00	-.5113-01	.2589-02	.6080-01	.1002+00
13	.260+02	.1514+00	-.4933-01	.2488-02	.6080-01	.1080+00
14	.290+02	.1358+00	-.4598-01	.2314-02	.5180-01	.1864+00
15	.292+02	.1221+00	-.4238-01	.2106-02	.4400-01	.1777+00
16	.322+02	.0018-01	-.3369-01	.1606-02	.2080-01	.1550+00
17	.376+02	.4529-01	-.1230-01	.7890-03	.8000-02	.1154+00
18	.400+02	.2958-01	-.1361-01	.5124-03	.8000-02	.9730-01
19	.406+02	.3294-01	-.1522-01	.5780-03	.4000-02	.1010+00
20	.418+02	.4060-01	-.1702-01	.7177-03	.7800-02	.1110+00
21	.442+02	.5757-01	-.2304-01	.1052-02	.1300-01	.1202+00
22	.472+02	.8261-01	-.3230-01	.1544-02	.2300-01	.1518+00
23	.502+02	.1126+00	-.4118-01	.2073-02	.3780-01	.1740+00
24	.532+02	.1451+00	-.5081-01	.2668-02	.5200-01	.1064+00
25	.562+02	.1793+00	-.6131-01	.3340-02	.6780-01	.2191+00
26	.592+02	.2151+00	-.7267-01	.4116-02	.8280-01	.2823+00
27	.622+02	.2517+00	-.8513-01	.5006-02	.9680-01	.2661+00
28	.652+02	.2892+00	-.9874-01	.6032-02	.1008+00	.2000+00
29	.682+02	.3282+00	-.1133+00	.7166-02	.1228+00	.2154+00
30	.700+02	.3511+00	-.1230+00	.7981-02	.1288+00	.2307+00

6. AND U10602

## MATERIAL DATA

MATERIAL IS AIR 3335-1

BULK MODULUS = .5000+06

VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

## TEST DATA

TYPE ... INITIAL

INITIAL STRAIN RATE = .6700+00

PRESSURE = 100. PSIG

TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	F11	F22	STRAINS (CALCULATED) E33	F12	TRUE STRESS (S11 - S22)
1	0.00	0.	-6666-04	-6666-04	-6666-04	.0000	.0000
2	9.00+00	0.	-1271-01	-5369-02	-5369-02	.0000	.2942+02
3	21.0+01	0.	-534-01	-1104-01	-1104-01	.0000	.633+02
4	336+01	0.	-6915-01	-1005-01	-1005-01	.0000	.0237+02
5	674+01	0.	-6632-01	-2991-01	-2991-01	.0000	.1835+03
6	172+01	0.	1025+00	-4279-01	-4279-01	.0000	.1972+03
7	107+02	0.	1263+00	-4990-01	-4990-01	.0000	.2264+03
8	112+02	0.	1263+00	-5012-01	-5012-01	.0000	.1807+03
9	124+02	0.	1263+00	-5021-01	-5021-01	.0000	.1470+03
10	142+02	0.	1263+00	-5035-01	-5035-01	.0000	.1227+03
11	170+02	0.	1263+00	-5052-01	-5052-01	.0000	.1060+03
12	233+02	0.	1263+00	-5066-01	-5066-01	.0000	.0660+02
13	317+02	0.	1263+00	-5088-01	-5088-01	.0000	.0260+02
14	322+02	0.	1223+00	-5258-01	-5258-01	.0000	.1345+03
15	436+02	0.	1475+00	-5675-01	-5675-01	.0000	.0873+03
16	540+02	0.	1628+00	-6060-01	-6060-01	.0000	.2423+03
17	364+02	0.	1862+00	-6601-01	-6601-01	.0000	.2672+03
18	393+02	0.	2179+00	-7238-01	-7238-01	.0000	.2841+03
19	418+02	0.	2586+00	-7993-01	-7993-01	.0000	.2063+03
20	430+02	0.	3004+00	-8514-01	-8514-01	.0000	.4062+03
21	402+02	0.	3495+00	-9250-01	-9250-01	.0000	.3146+03
22	484+02	0.	3469+00	-9245-01	-9245-01	.0000	.2790+03
23	407+02	0.	3392+00	-9204-01	-9204-01	.0000	.2016+03
24	507+02	0.	3209+00	-9093-01	-9093-01	.0000	.1352+03
25	520+02	0.	3254+00	-8858-01	-8858-01	.0000	.2657+02
26	506+02	0.	2619+00	-7951-01	-7951-01	.0000	.2793+02
27	575+02	0.	2211+00	-7791-01	-7791-01	.0000	.3175+03
28	535+02	0.	2211+00	-7791-01	-7791-01	.0000	.3771+02
29	582+02	0.	2211+00	-7795-01	-7795-01	.0000	.2948+02
30	610+02	0.	2211+00	-7799-01	-7799-01	.0000	.2606+02
31	534+02	0.	2211+00	-7816-01	-7816-01	.0000	.2727+02
32	580+02	0.	2211+00	-7854-01	-7854-01	.0000	.2820+02
33	740+02	0.	2211+00	-7883-01	-7883-01	.0000	.2000+02
34	808+02	0.	2211+00	-7908-01	-7908-01	.0000	.2040+02
35	814+02	0.	2292+00	-8067-01	-8067-01	.0000	.1017+03
36	826+02	0.	2455+00	-8363-01	-8363-01	.0000	.1275+03
37	864+02	0.	2702+00	-8735-01	-8735-01	.0000	.1750+03
38	874+02	0.	3123+00	-9224-01	-9224-01	.0000	.2423+03
39	908+02	0.	3556+00	-9683-01	-9683-01	.0000	.2681+03
40	930+02	0.	4000+00	-1013+00	-1013+00	.0000	.2210+03
41	703+02	0.	4455+00	-1050+00	-1050+00	.0000	.2507+03
42	394+02	0.	4021+00	-1102+00	-1102+00	.0000	.2337+03
43	102+03	0.	5399+00	-1145+00	-1145+00	.0000	.2527+03
44	105+03	0.	5087+00	-1192+00	-1192+00	.0000	.2527+03

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## MATERIAL DATA

MATERIAL IS AIR 3335-1

BULK MODULUS = .5000+06

VOLUME TRIC EXPANSION COEFFICIENT = .1800-03

## TEST DATA

TYPE ... INITIAL

INITIAL STRAIN RATE = .6700+00

PRESSURE = 100. 0CIG

TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	11	12	13	CORRECTED DILATION	OCTAHEDRAL STRAIN
1	.000	-.2000-03	.1333-07	-.2063-12	-.2000-03	.1054-07
2	.060+00	-.2005-04	-.0618-04	.5000-06	-.2000-03	.7500-02
3	.216+01	.6500-03	-.4363-03	.3014-05	-.2000-03	.3700-01
4	.336+01	.2050-02	-.1052-02	.1243-04	.0015-07	.2450-01
5	.576+01	.6600-02	-.3065-02	.5000-04	.0001-03	.4050-01
6	.876+01	.1600-01	-.6004-02	.1070-03	.3000-02	.6051-01
7	.107+02	.2632-01	-.1013-01	.3156-03	.7300-02	.0310-01
8	.112+02	.2605-01	-.1015-01	.3173-03	.7000-02	.0316-01
9	.124+02	.2507-01	-.1010-01	.3184-03	.6000-02	.0321-01
10	.142+02	.2561-01	-.1018-01	.3201-03	.6500-02	.0307-01
11	.172+02	.2525-01	-.1021-01	.3224-03	.6100-02	.0300-01
12	.232+02	.2400-01	-.1023-01	.3241-03	.5000-02	.0302-01
13	.317+02	.2453-01	-.1026-01	.3270-03	.5300-02	.0352-01
14	.322+02	.2715-01	-.1115-01	.3658-03	.6300-02	.0716-01
15	.334+02	.3007-01	-.1152-01	.4740-03	.0000-02	.0000-02
16	.346+02	.4160-01	-.1606-01	.5000-03	.1100-01	.1050-01
17	.364+02	.5413-01	-.2022-01	.8111-03	.1600-01	.1100-01
18	.380+02	.7315-01	-.2630-01	.1142-02	.2400-01	.1300-01
19	.410+02	.1007+00	-.3060-01	.1611-02	.3730-01	.1501+00
20	.440+02	.1301+00	-.4301-01	.2170-02	.4000-01	.1010+00
21	.462+02	.1645+00	-.5610-01	.2090-02	.6230-01	.2000+00
22	.484+02	.1620+00	-.5550-01	.2065-02	.6000-01	.2071+00
23	.500+02	.1540+00	-.5380-01	.2067-02	.5630-01	.2070+00
24	.502+02	.1300+00	-.5009-01	.2654-02	.4030-01	.1041+00
25	.520+02	.1102+00	-.4040-01	.2317-02	.3700-01	.1010+00
26	.540+02	.0200-01	-.3712-01	.1470-02	.2500-01	.1630+00
27	.574+02	.6530-01	-.2819-01	.1342-02	.1300-01	.1410+00
28	.590+02	.6530-01	-.2839-01	.1342-02	.1300-01	.1410+00
29	.592+02	.6521-01	-.2840-01	.1344-02	.1370-01	.1410+00
30	.610+02	.6513-01	-.2841-01	.1345-02	.1360-01	.1410+00
31	.634+02	.6400-01	-.2846-01	.1351-02	.1320-01	.1411+00
32	.660+02	.6405-01	-.2856-01	.1364-02	.1230-01	.1412+00
33	.740+02	.6377-01	-.2865-01	.1374-02	.1160-01	.1414+00
34	.800+02	.6207-01	-.2872-01	.1383-02	.1100-01	.1415+00
35	.814+02	.6705-01	-.3047-01	.1491-02	.1200-01	.1461+00
36	.826+02	.7020-01	-.3006-01	.1717-02	.1600-01	.1551+00
37	.844+02	.0550-01	-.3058-01	.2062-02	.2030-01	.1600+00
38	.874+02	.1270+00	-.4011-01	.2657-02	.3050-01	.1007+00
39	.900+02	.1610+00	-.5049-01	.3334-02	.5000-01	.2130+00
40	.934+02	.1974+00	-.7070-01	.4105-02	.6000-01	.2360+00
41	.964+02	.2336+00	-.8316-01	.0000-02	.0000-01	.2550+00
42	.994+02	.2710+00	-.0620-01	.5071-02	.0030-01	.2050+00
43	.102+03	.3100+00	-.1105+00	.7082-02	.1110-01	.3000+00
44	.105+03	.3503+00	-.1262+00	.8367-02	.1230-01	.3370+00

# SUMMARY OF TEST P.O. 410604

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## MATERIAL DATA

MATERIAL IS AISH 3034-1  
BULK MODULUS =  $5.600 \times 10^6$   
VOLUME-ETRIC EXPANSION COEFFICIENT =  $1.800 \times 10^{-5}$

## TEST DATA

TYPE ... INITIAL  
INITIAL STRAIN RATE =  $.6700 \times 10^{-3}$   
PRESSURE = 100. PSIG  
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	F11	F22	F33	STRAINS (CALCULATED)	E12	TRUE STRESS (S11 - S22)
1	.000	0.	-.6668-04	-.6666-04	-.6666-04	-.6666-04	.0000	.0000
2	.120+01	0.	.1342-01	-.6678-02	-.6678-02	-.6678-02	.0000	.2230+02
3	.240+01	0.	.2709-01	-.1312-01	-.1312-01	-.1312-01	.0000	.5442+02
4	.360+01	0.	.4094-01	-.1934-01	-.1934-01	-.1934-01	.0000	.2000+02
5	.480+01	0.	.6917-01	-.3009-01	-.3009-01	-.3009-01	.0000	.1260+02
6	.600+01	0.	.1055+00	-.4409-01	-.4409-01	-.4409-01	.0000	.1913+02
7	.120+02	0.	.1429+00	-.5544-01	-.5544-01	-.5544-01	.0000	.2213+02
8	.150+02	0.	.1415+00	-.6533-01	-.6533-01	-.6533-01	.0000	.2480+02
9	.160+02	0.	.2211+00	-.7300-01	-.7300-01	-.7300-01	.0000	.2656+02
10	.216+02	0.	.2619+00	-.7980-01	-.7980-01	-.7980-01	.0000	.2776+02
11	.240+02	0.	.3038+00	-.8614-01	-.8614-01	-.8614-01	.0000	.2871+02
12	.270+02	0.	.3469+00	-.9180-01	-.9180-01	-.9180-01	.0000	.2922+02
13	.300+02	0.	.3910+00	-.9713-01	-.9713-01	-.9713-01	.0000	.2990+02
14	.330+02	0.	.4363+00	-.1021+00	-.1021+00	-.1021+00	.0000	.3042+02
15	.360+02	0.	.4827+00	-.1067+00	-.1067+00	-.1067+00	.0000	.3184+02

# SUMMARY OF TEST NO. 110605

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## TEST DATA

TEST NO. 110605-1

POLE MODULUS = .5000+06

VOLUME FRICTION EXPANSION COEFFICIENT = .1000-03

## TEST DATA

TYPE ... UNIAxIAL

INITIAL STRAIN RATE = .6700+00

PRESSURE = 100. PCIF

TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	STRAIN INVARIANTS			CORRECTION DILATATION	OCTAHEDRAL STRAIN
		I1	I2	I3		
1	.000	-.2000-03	.1333-07	-.2063-12	-.2000-05	.1054-07
2	.120+01	.6600-04	-.1347-03	.5085-06	-.2000-03	.0475-02
3	.240+01	.8500-03	-.5386-03	.4660-05	-.2000-03	.1065-01
4	.360+01	.7250-02	-.1209-02	.1531-04	-.9996-04	.2042-01
5	.480+01	.7160-02	-.1327-02	.6644-04	.0001-03	.4722-01
6	.600+01	.1730-01	-.7457-02	.2050-03	.3400-02	.7057-01
7	.120+02	.5202-01	-.1277-01	.4392-03	.0209-02	.9350-01
8	.150+02	.5070-01	-.1044-01	.7744-03	.1490-01	.1163+00
9	.180+02	.7512-01	-.2695-01	.1178-02	.2560-01	.1765+00
10	.210+02	.1021+00	-.3547-01	.1672-02	.3720-01	.1411+00
11	.240+02	.1316+00	-.4402-01	.2234-02	.0650-01	.1870+00
12	.270+02	.1633+00	-.5260-01	.2823-02	.6350-01	.2064+00
13	.300+02	.1948+00	-.6653-01	.3689-02	.7560-01	.2301+00
14	.330+02	.2322+00	-.7064-01	.4545-02	.8910-01	.2538+00
15	.360+02	.2693+00	-.8161-01	.5494-02	.1028+00	.2774+00

W ADD 110605

# SUMMARY OF T F S T N O . 010605

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## M A T E R I A L D A T A

MATERIAL TS AIR 3334-1

BULK MODULUS -5000+06

VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

## T F S T N A T A

TYPE \*\*\* UNIAXIAL

INITIAL STRAIN RATE = .4700+00

PRESSURE = 200. PCIF

TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG. F	F11	F22	STRAINS (CALCULATED) E33	F12	TRUE STRESS (S11 - E22)
1	.060	0.	.1233-03	-.1333-03	-.1333-03	.0000	.0000
2	.220+00	0.	.1338-02	-.4121-02	-.4121-02	.0000	.2520+02
3	.222+01	0.	.2046-01	-.1223-01	-.1223-01	.0000	.1047+02
4	.222+01	0.	.5085-01	-.2753-01	-.2753-01	.0000	.1270+03
5	.222+01	0.	.6586-01	-.4161-01	-.4161-01	.0000	.1010+03
6	.112+02	0.	.1730+00	-.5055-01	-.5055-01	.0000	.2427+03
7	.142+02	0.	.1712+00	-.6610-01	-.6610-01	.0000	.2808+03
8	.172+02	0.	.2106+00	-.7678-01	-.7678-01	.0000	.1074+03
9	.202+02	0.	.2511+00	-.8651-01	-.8651-01	.0000	.1263+03
10	.232+02	0.	.2927+00	-.9540-01	-.9540-01	.0000	.1405+03
11	.262+02	0.	.3355+00	-.1038+00	-.1038+00	.0000	.2822+03
12	.262+02	0.	.3793+00	-.1117+00	-.1117+00	.0000	.3371+03
13	.342+02	0.	.4243+00	-.1192+00	-.1192+00	.0000	.4047+03
14	.352+02	0.	.4704+00	-.1264+00	-.1264+00	.0000	.4066+03
15	.382+02	0.	.5177+00	-.1334+00	-.1334+00	.0000	.4526+03
16	.412+02	0.	.5660+00	-.1401+00	-.1401+00	.0000	.5184+03

# SUMMARY OF TEST NO. U10605

PAGE U10605 - 2

## MATERIAL DATA

MATERIAL IS AIR 334-1  
PULS FOCUS = .500+06  
VOLUME FRICTION COEFFICIENT = .1800-03

## TEST DATA

TYPE ... INSTANTIAL  
INITIAL STRAIN RATE = .6700+00  
PRESSURE = 200. PSI  
TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	I1	STRAIN INVARIANTS I2	I3	CORRECTED DILATATION	ACTUAL STRAIN
1	.000	-.4000-03	.5334-07	-.2371-11	-.4000-03	.0000
2	.720+00	-.3036-03	-.4844-04	.1348-06	-.4000-03	.6882-02
3	.722+01	.5069-03	-.4609-03	.3732-05	-.4000-03	.1753-01
4	.522+01	.4793-02	-.2537-02	.4375-04	-.6004-04	.4115-01
5	.622+01	.1263-01	-.6246-02	.1660-03	.9001-03	.6460-01
6	.112+02	.2389-01	-.1153-01	.3057-03	.2400-02	.8041-01
7	.142+02	.3869-01	-.1029-01	.7500-03	.5300-02	.1110+00
8	.172+02	.5707-01	-.2643-01	.1241-02	.6100-02	.1355+00
9	.202+02	.7810-01	-.3506-01	.1870-02	.1360-01	.1502+00
10	.232+02	.1010+00	-.4675-01	.2664-02	.1890-01	.1830+00
11	.262+02	.1220+00	-.5885-01	.3612-02	.2400-01	.2071+00
12	.292+02	.1560+00	-.7225-01	.4730-02	.3000-01	.2315+00
13	.322+02	.1860+00	-.8693-01	.6026-02	.3560-01	.2552+00
14	.352+02	.2177+00	-.1020+00	.7515-02	.4100-01	.2813+00
15	.382+02	.2509+00	-.1203+00	.9200-02	.4610-01	.3069+00
16	.412+02	.2859+00	-.1389+00	.1111-01	.5110-01	.3320+00

## MATERIAL DATA

MATERIAL IS ANR 3335-1  
 BULK MODULUS = -5000+06  
 VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

## TEST DATA

TYPE ... UNIAxIAL  
 INITIAL STRAIN RATE = .6700+00  
 PRESSURE = 200. PSIC  
 TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	F11	F22	STRAINS (CALCULATED)	E12	TOTAL STRESS (S11 - S22)
1	.000	0.	-.1333-03	-.1333-03	-.1333-03	.0000	.0000
2	.600+00	0.	.6500-02	-.3461-02	-.3461-02	.0000	.2830+02
3	.180+01	0.	.2017-01	-.9884-02	-.9884-02	.0000	.5611+02
4	.370+01	0.	.3392-01	-.1622-01	-.1622-01	.0000	.9611+02
5	.600+01	0.	.6010-01	-.3002-01	-.3002-01	.0000	.1663+03
6	.900+01	0.	.1054+00	-.4300-01	-.4300-01	.0000	.2284+03
7	.120+02	0.	.1020+00	-.5533-01	-.5533-01	.0000	.2765+03
8	.150+02	0.	.1014+00	-.6530-01	-.6530-01	.0000	.3014+03
9	.180+02	0.	.2210+00	-.7381-01	-.7381-01	.0000	.3335+03
10	.210+02	0.	.2618+00	-.8100-01	-.8100-01	.0000	.3510+03
11	.216+02	0.	.2613+00	-.8173-01	-.8173-01	.0000	.3507+03
12	.220+02	0.	.2618+00	-.8234-01	-.8234-01	.0000	.3577+03
13	.246+02	0.	.2610+00	-.8204-01	-.8204-01	.0000	.3511+03
14	.276+02	0.	.2618+00	-.8355-01	-.8355-01	.0000	.3106+03
15	.336+02	0.	.2618+00	-.8436-01	-.8436-01	.0000	.1901+03
16	.455+02	0.	.2618+00	-.8520-01	-.8520-01	.0000	.1732+03
17	.635+02	0.	.2618+00	-.8610-01	-.8610-01	.0000	.1612+03
18	.813+02	0.	.2610+00	-.8667-01	-.8667-01	.0000	.1527+03
19	.916+02	0.	.2660+00	-.8660-01	-.8660-01	.0000	.1473+03
20	.136+03	0.	.2826+00	-.8809-01	-.8809-01	.0000	.2554+03
21	.186+03	0.	.3000+00	-.9256-01	-.9256-01	.0000	.2507+03
22	.236+03	0.	.3337+00	-.9603-01	-.9603-01	.0000	.2603+03
23	.282+03	0.	.3500+00	-.9804-01	-.9804-01	.0000	.2762+03
24	.306+03	0.	.3054+00	-.1038+00	-.1038+00	.0000	.2806+03
25	.337+03	0.	.4426+00	-.1066+00	-.1066+00	.0000	.2815+03
26	.384+03	0.	.4426+00	-.1109+00	-.1109+00	.0000	.2564+03
27	.428+03	0.	.4426+00	-.1107+00	-.1107+00	.0000	.2564+03
28	.472+03	0.	.4426+00	-.1135+00	-.1135+00	.0000	.2808+03
29	.506+03	0.	.4426+00	-.1123+00	-.1123+00	.0000	.2808+03
30	.556+03	0.	.4426+00	-.1134+00	-.1134+00	.0000	.2611+03
31	.618+03	0.	.4426+00	-.1160+00	-.1160+00	.0000	.2612+03
32	.635+03	0.	.4426+00	-.1163+00	-.1163+00	.0000	.2100+03
33	.651+03	0.	.4426+00	-.1172+00	-.1172+00	.0000	.1660+03
34	.652+03	0.	.4426+00	-.1175+00	-.1175+00	.0000	.2818+03
35	.657+03	0.	.4723+00	-.1180+00	-.1180+00	.0000	.2935+03
36	.656+03	0.	.5106+00	-.1227+00	-.1227+00	.0000	.2755+03
37	.659+03	0.	.5680+00	-.1272+00	-.1272+00	.0000	.2062+03

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## MATERIAL DATA

MATERIAL IS AIR 3335-1  
 BULK MODULUS = .5000+06  
 VOLUMETRIC EXPANSION COEFFICIENT = .1800-03  
 TYPE ... INITIAL  
 INITIAL STRAIN RATE = .4700+00  
 PRESSURE = 200. PSIG  
 TEMPERATURE IS CONSTANT

## TEST DATA

DATA POINT	TIME SFC.	STRAIN INVARIANTS			CORRECTED DILATATION	OCTAHEDRAL STRAIN
		I1	I2	I3		
1	.000	-.4000-03	-.5334-07	-.2371-11	-.4000-03	.0000
2	.600+00	-.3330-03	-.3762-04	.7890-07	-.4000-03	.4737-02
3	.100+01	.1980-03	-.3030-03	.2010-05	-.4000-03	.1421-01
4	.300+01	.1489-02	-.8173-03	.8020-05	-.1500-03	.2364-01
5	.600+01	.7458-02	-.3310-02	.6565-04	.1100-02	.4710-01
6	.900+01	.1768-01	-.7325-02	.2020-03	.3800-02	.7037-01
7	.120+02	.3217-01	-.1274-01	.4372-03	.8400-02	.0341-01
8	.150+02	.5077-01	-.1042-01	.7735-03	.1490-01	.1163+00
9	.180+02	.7342-01	-.2718-01	.1204-02	.2360-01	.1308+00
10	.210+02	.9886-01	-.3603-01	.1730-02	.3320-01	.1618+00
11	.246+02	.6837-01	-.2612-01	.1749-02	.3260-01	.1620+00
12	.228+02	.0716-01	-.3634-01	.1775-02	.3110-01	.1622+00
13	.246+02	.0594-01	-.3655-01	.1801-02	.2960-01	.1625+00
14	.276+02	.0473-01	-.3677-01	.1826-02	.2810-01	.1628+00
15	.336+02	.0311-01	-.3706-01	.1863-02	.2610-01	.1632+00
16	.456+02	.0124-01	-.3730-01	.1905-02	.2380-01	.1636+00
17	.636+02	.0062-01	-.3768-01	.1941-02	.2180-01	.1640+00
18	.813+02	.0049-01	-.3787-01	.1967-02	.2040-01	.1643+00
19	.816+02	.0201-01	-.3870-01	.2012-02	.2240-01	.1664+00
20	.828+02	.1045+00	-.4242-01	.2243-02	.2820-01	.1752+00
21	.846+02	.1220+00	-.4845-01	.2638-02	.3590-01	.1888+00
22	.864+02	.1417+00	-.5488-01	.3078-02	.4330-01	.2026+00
23	.882+02	.1610+00	-.6169-01	.3550-02	.5060-01	.2165+00
24	.906+02	.1878+00	-.7131-01	.4260-02	.6040-01	.2353+00
25	.937+02	.2235+00	-.8499-01	.5313-02	.7220-01	.2603+00
26	.942+02	.2228+00	-.8523-01	.5348-02	.7120-01	.2605+00
27	.954+02	.2213+00	-.8574-01	.5423-02	.6910-01	.2608+00
28	.972+02	.2197+00	-.8627-01	.5502-02	.6690-01	.2612+00
29	.996+02	.2181+00	-.8677-01	.5578-02	.6480-01	.2616+00
30	.106+03	.2158+00	-.8754-01	.5654-02	.6160-01	.2621+00
31	.118+03	.2128+00	-.8852-01	.5845-02	.5750-01	.2628+00
32	.136+03	.2100+00	-.8945-01	.5990-02	.5360-01	.2635+00
33	.151+03	.2083+00	-.9000-01	.6077-02	.5130-01	.2639+00
34	.152+03	.2188+00	-.9200-01	.6202-02	.5603+00	.2603+00
35	.153+03	.2344+00	-.9820-01	.6681-02	.6280-01	.2707+00
36	.156+03	.2742+00	-.1124+00	.7821-02	.7760-01	.3028+00
37	.159+03	.3135+00	-.1283+00	.9194-02	.8960-01	.3277+00

TEST DATA

TYPE ... UNIAxIAL

INITIAL STRAIN RATE = .2700+00

PRESSURE = 200.0 PSI

TEMPERATURE IS CONSTANT

POISSON'S RATIO = .5000+05

MECHANICAL EXTENSION COEFFICIENT = .1000-03

TEST DATA

TYPE ... UNIAxIAL

INITIAL STRAIN RATE = .2700+00

PRESSURE = 200.0 PSI

TEMPERATURE IS CONSTANT

TIME STRESS  
(C31 - C22)

F12

STRESS (CALCULATED)  
E2

F11

TEMP.  
DEG.-F

DATA  
POINT

DATA POINT	TIME SEC.	TEMP. DEG.-F	STRESS (CALCULATED) E2	F12	TIME STRESS (C31 - C22)
1	.000	0.	-.1333-03	.0000	.0000
2	.720+00	0.	-.4121-02	.0000	.2821+02
3	.162+01	0.	-.1643-01	.0000	.6844+02
4	.372+01	0.	-.1600-01	.0000	.1156+03
5	.672+01	0.	-.3433-01	.0000	.1002+03
6	.972+01	0.	-.4705-01	.0000	.2544+03
7	.127+02	0.	-.5802-01	.0000	.3001+03
8	.167+02	0.	-.6734-01	.0000	.3310+03
9	.165+02	0.	-.7004-01	.0000	.3301+03
10	.160+02	0.	-.7012-01	.0000	.3326+03
11	.175+02	0.	-.7038-01	.0000	.3506+03
12	.187+02	0.	-.7076-01	.0000	.2201+03
13	.265+02	0.	-.7114-01	.0000	.2057+03
14	.235+02	0.	-.7144-01	.0000	.1982+03
15	.280+02	0.	-.7211-01	.0000	.1718+03
16	.400+02	0.	-.7286-01	.0000	.1543+03
17	.440+02	0.	-.7303-01	.0000	.1300+03
18	.411+02	0.	-.7239-01	.0000	.2214+02
19	.703+02	0.	-.6876-01	.0000	.5231+02
20	.721+02	0.	-.6272-01	.0000	.1144+02
21	.727+02	0.	-.6517-01	.0000	.2913+02
22	.750+02	0.	-.6957-01	.0000	.7765+02
23	.763+02	0.	-.7661-01	.0000	.1765+03
24	.741+02	0.	-.8001-01	.0000	.2444+03
25	.793+02	0.	-.8381-01	.0000	.1555+03
26	.805+02	0.	-.8654-01	.0000	.2476+03
27	.817+02	0.	-.8925-01	.0000	.3642+03
28	.847+02	0.	-.9567-01	.0000	.3884+03
29	.877+02	0.	-.1018+00	.0000	.4003+03
30	.907+02	0.	-.1074+00	.0000	.4063+03
31	.937+02	0.	-.1128+00	.0000	.4108+03
32	.955+02	0.	-.1159+00	.0000	.4113+03

# SUMMARY OF TEST NO. U10607

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## MATERIAL DATA

MATERIAL IS ANR 3335-1  
 BULK MODULUS = .5000+06  
 VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

## TEST DATA

TYPE ... UNIAXIAL  
 INITIAL STRAIN RATE = .6700+00  
 PRESSURE = 200. PCIF  
 TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	STRAIN INVARIANTS			CORRECTED DILATATION	OCTAHEDRAL STRAIN
		I1	I2	I3		
1	.000	-.4000-03	.5334-07	-.2371-11	-.4000-03	.0000
2	.720+00	-.4036-03	-.4844-04	.1348-06	-.4000-03	.5485-02
3	.192+01	-.3768-03	-.3447-03	.2432-05	-.4000-03	.1516-01
4	.372+01	.2456-02	-.1286-02	.1674-04	-.4096-04	.2031-01
5	.672+01	.0049-02	-.4157-02	.9160-04	.1100-02	.5282-01
6	.972+01	.2018-01	-.8541-02	.2530-03	.4100-02	.7605-01
7	.127+02	.3504-01	-.1427-01	.5116-03	.0400-02	.6800-01
8	.157+02	.5611-01	-.2116-01	.8652-03	.1710-01	.9217+00
9	.166+02	.6258-01	-.2148-01	.0041-03	.1040-01	.1205+00
10	.169+02	.6241-01	-.2350-01	.0965-03	.1020-01	.1286+00
11	.175+02	.6190-01	-.2357-01	.1004-02	.1860-01	.1287+00
12	.187+02	.6114-01	-.2367-01	.1015-02	.1770-01	.1280+00
13	.205+02	.6038-01	-.2377-01	.1024-02	.1680-01	.1201+00
14	.235+02	.5937-01	-.2390-01	.1040-02	.1560-01	.1203+00
15	.283+02	.5844-01	-.2403-01	.1054-02	.1450-01	.1205+00
16	.409+02	.5692-01	-.2422-01	.1074-02	.1270-01	.1200+00
17	.685+02	.5498-01	-.2447-01	.1104-02	.1040-01	.1103+00
18	.691+02	.4066-01	-.2295-01	.1020-02	.8100-02	.1250+00
19	.703+02	.4151-01	-.1989-01	.8468-03	.5100-02	.1168+00
20	.721+02	.3037-01	-.1561-01	.6120-03	.1600-02	.1070+00
21	.727+02	.3315-01	-.1706-01	.6045-03	.1800-02	.1070+00
22	.739+02	.3088-01	-.2007-01	.8666-03	.3200-02	.1172+00
23	.763+02	.5740-01	-.2640-01	.1234-02	.5000-02	.1354+00
24	.781+02	.7267-01	-.3144-01	.1537-02	.1610-01	.1408+00
25	.793+02	.8349-01	-.3507-01	.1768-02	.2020-01	.1579+00
26	.805+02	.9055-01	-.3983-01	.2008-02	.2460-01	.1670+00
27	.817+02	.1058+00	-.4270-01	.2265-02	.2850-01	.1761+00
28	.847+02	.1355+00	-.5339-01	.2992-02	.3000-01	.1902+00
29	.877+02	.1669+00	-.6507-01	.3848-02	.5080-01	.2266+00
30	.907+02	.2005+00	-.7765-01	.4788-02	.6240-01	.2464+00
31	.937+02	.2356+00	-.9128-01	.5863-02	.7380-01	.2705+00
32	.955+02	.2575+00	-.9994-01	.6568-02	.8060-01	.2852+00

END U10607

## MATERIAL DATA

MATERIAL IS AHS 3335-1

BULK MODULUS =  $5.00 \times 10^6$ VOLUMETRIC EXPANSION COEFFICIENT =  $1.000 \times 10^{-3}$ 

## TEST DATA

TYPE ... INITIAL

INITIAL STRAIN RATE =  $1.700 \times 10^0$ 

PRESSURE = 200. PSIG

TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	STRAINS (CALCULATED)		E12	TIME STRESS (E11 - E22)
			F11	F22		
1	.000	0.	-.1333-03	-.1333-03	.0000	.0000
2	.040+00	0.	.0289-02	-.4770-02	.0000	.0028+02
3	.324+01	0.	.3770-01	-.1759-01	.0000	.0601+02
4	.504+01	0.	.5772-01	-.2663-01	.0000	.1320+03
5	.704+01	0.	.9366-01	-.4045-01	.0000	.2025+03
6	.110+02	0.	.1307+00	-.5273-01	.0000	.2611+03
7	.140+02	0.	.1689+00	-.6316-01	.0000	.3026+03
8	.170+02	0.	.2082+00	-.7224-01	.0000	.3302+03
9	.206+02	0.	.2560+00	-.8179-01	.0000	.3505+03
10	.242+02	0.	.2987+00	-.9101-01	.0000	.3636+03
11	.280+02	0.	.3293+00	-.7800-01	.0000	.3706+03
12	.324+02	0.	.1024+00	-.7221-01	.0000	.3802+03
13	.368+02	0.	.1744+00	-.6770-01	.0000	.4093+03
14	.378+02	0.	.1744+00	-.6783-01	.0000	.4706+02
15	.396+02	0.	.1744+00	-.6787-01	.0000	.4601+02
16	.420+02	0.	.1744+00	-.6701-01	.0000	.4724+02
17	.430+02	0.	.1744+00	-.6800-01	.0000	.4840+02
18	.500+02	0.	.1744+00	-.6824-01	.0000	.4631+02
19	.622+02	0.	.1744+00	-.6851-01	.0000	.4390+02
20	.632+02	0.	.1089+00	-.7235-01	.0000	.4206+03
21	.650+02	0.	.2122+00	-.7763-01	.0000	.4300+03
22	.680+02	0.	.2529+00	-.8484-01	.0000	.3800+03
23	.633+02	0.	.2776+00	-.9207-01	.0000	.3317+03
24	.710+02	0.	.2084+00	-.9560-01	.0000	.3533+03
25	.740+02	0.	.3772+00	-.9791-01	.0000	.3702+03
26	.760+02	0.	.3785+00	-.1034+00	.0001	.3317+03
27	.776+02	0.	.3785+00	-.1034+00	.0001	.3723+03
28	.783+02	0.	.3785+00	-.1044+00	.0000	.3925+03
29	.806+02	0.	.3785+00	-.1050+00	.0000	.3681+03
30	.830+02	0.	.3785+00	-.1053+00	.0000	.3375+03
31	.850+02	0.	.3785+00	-.1061+00	.0000	.3335+03
32	.920+02	0.	.3785+00	-.1069+00	.0000	.3101+03
33	.101+03	0.	.3785+00	-.1076+00	.0000	.2840+03
34	.102+03	0.	.3811+00	-.1076+00	.0000	.2805+03
35	.103+03	0.	.3800+00	-.1091+00	.0000	.3038+03
36	.105+03	0.	.4262+00	-.1119+00	.0000	.3668+03
37	.106+03	0.	.4637+00	-.1146+00	.0000	.3925+03
38	.109+03	0.	.4011+00	-.1184+00	.0000	.3047+03
39	.112+03	0.	.5788+00	-.1234+00	.0000	.4067+03
40	.115+03	0.	.5877+00	-.1289+00	.0000	.3075+03

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ORIGINAL DATA

POTENTIAL IS 400 3335-1  
 POLAR EQUILIBRIUM = 5000+06  
 VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... INITIAL  
 INITIAL STRAIN RATE = .6700+00  
 PRESSURE = 200. PSI  
 TEMPERATURE IS CONSTANT

DATA POINT	TIME SFC.	STRAIN INVAPIANTS	11	12	13	CORRECTION INFLATION	OCTAHERPAL STRAIN
1	.000						
2	.040+00						
3	.324+01						
4	.504+01						
5	.004+01						
6	.110+02						
7	.140+02						
8	.170+02						
9	.206+02						
10	.212+02						
11	.230+02						
12	.254+02						
13	.268+02						
14	.278+02						
15	.206+02						
16	.320+02						
17	.300+02						
18	.500+02						
19	.622+02						
20	.632+02						
21	.650+02						
22	.680+02						
23	.698+02						
24	.710+02						
25	.740+02						
26	.768+02						
27	.776+02						
28	.708+02						
29	.806+02						
30	.80+02						
31	.860+02						
32	.920+02						
33	.103+03						
34	.102+03						
35	.103+03						
36	.105+03						
37	.106+03						
38	.109+03						
39	.112+03						
40	.115+03						

## SUMMARY OF TEST NO. U10609

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## MATERIAL DATA

MATERIAL IS ANH 335-1

BULK MODULUS = .5000+06

VOLUME-FRIC EXPANSION COEFFICIENT = .1800-03

## TEST DATA

TYPE ... UNIAxIAL

INITIAL STRAIN RATE = .6700+00

PRESSURE = 500. PSIG

TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	F11	F22	STRAINS (CALCULATED) E11	E12	TRIF STRESS (S11 - S22)
1	.000	0.	-.3334-03	-.3334-03	-.3334-03	.0000	.0000
2	.600+00	0.	.5397-02	-.3660-02	-.3660-02	.0000	.5323+02
3	.300+01	0.	.3372-01	-.1653-01	-.1653-01	.0000	.5023+02
4	.540+01	0.	.6176-01	-.2862-01	-.2862-01	.0000	.5644+02
5	.840+01	0.	.9783-01	-.4260-01	-.4260-01	.0000	.5231+02
6	.114+02	0.	.1350+00	-.5558-01	-.5558-01	.0000	.5074+02
7	.144+02	0.	.1733+00	-.6746-01	-.6746-01	.0000	.5776+02
8	.174+02	0.	.2128+00	-.7830-01	-.7830-01	.0000	.5260+02
9	.204+02	0.	.2533+00	-.8814-01	-.8814-01	.0000	.5626+02
10	.234+02	0.	.2950+00	-.9725-01	-.9725-01	.0000	.5005+02
11	.264+02	0.	.3378+00	-.1058+00	-.1058+00	.0000	.5125+02
12	.294+02	0.	.3817+00	-.1139+00	-.1139+00	.0000	.5272+02
13	.324+02	0.	.4268+00	-.1217+00	-.1217+00	.0000	.5375+02
14	.354+02	0.	.4730+00	-.1292+00	-.1292+00	.0000	.5845+02

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# SUMMARY OF TEST NO. U0609

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## MATERIAL DATA

MATERIAL IS ANR 3335-1  
 BULK MODULUS = .5000+06  
 VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

## TEST DATA

TYPE ... INITIAL  
 INITIAL STRAIN RATE = 1.4700+00  
 PRESSURE = 500. PSIG  
 TEMPERATURE IS CONSTANT

DATA POINT	TIME SFC.	STRAIN INVARIANTS			CORRECTED DILATATION	OCTAHEDRAL STRESS
		I1	I2	I3		
1	.000	-.1000-02	.3334-06	-.3705-10	-.1000-02	.3512-03
2	.600+00	-.0331-03	-.3336-04	.8555-07	-.1000-02	.4736-03
3	.300+01	.6460-03	-.8416-03	.9218-05	-.1000-02	.2760-01
4	.540+01	.4530-02	-.2716-02	.5058-04	-.6000-03	.4261-01
5	.840+01	.1245-01	-.6531-02	.1783-03	.1001-03	.6625-01
6	.114+02	.2387-01	-.1192-01	.4171-03	.1700-02	.8085-01
7	.144+02	.3842-01	-.1884-01	.7888-03	.3000-02	.8135+00
8	.174+02	.5619-01	-.2719-01	.1304-02	.7000-02	.1372+00
9	.204+02	.7707-01	-.3680-01	.1968-02	.1110-01	.1410+00
10	.234+02	.1005+00	-.4702-01	.2790-02	.1570-01	.1940+00
11	.264+02	.1263+00	-.6028-01	.3780-02	.2060-01	.2071+00
12	.294+02	.1539+00	-.7400-01	.4954-02	.2500-01	.2337+00
13	.324+02	.1855+00	-.8905-01	.6317-02	.3020-01	.2685+00
14	.354+02	.2146+00	-.1055+00	.7891-02	.3460-01	.2838+00

## MATERIAL DATA

MATERIAL IS AL 3335-1

BULK MODULUS = .5000+06

VOLUME TRIC EXPANSION COEFFICIENT = .1800-03

## TEST DATA

TYPE ... BIAXIAL

INITIAL STRAIN RATE = .6700+00

PRESSURE = 0. PSTG

TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	F11	STRAINS (CALCULATED) E22	E12	TIME STRESS (S11 - S22)
1	.000	0.	.0000	.0000	.0000	.0000
2	.600+00	0.	.6722-02	.6633-02	.0000	.2517+02
3	.180+01	0.	.2030-01	.1941-01	.0000	.6036+02
4	.300+01	0.	.3406-01	.3170-01	.0000	.1085+03
5	.360+01	0.	.3806-01	.3161-01	.0000	.0473+02
6	.480+01	0.	.3406-01	.3142-01	.0000	.6923+02
7	.720+01	0.	.3406-01	.3133-01	.0000	.6476+02
8	.130+02	0.	.3406-01	.3123-01	.0000	.8586+02
9	.252+02	0.	.3406-01	.3123-01	.0000	.8710+02
10	.402+02	0.	.3406-01	.3133-01	.0000	.8806+02
11	.414+02	0.	.3662-01	.3615-01	.0000	.7780+02
12	.426+02	0.	.6733-01	.4753-01	.0000	.1673+03
13	.449+02	0.	.7409-01	.6276-01	.0000	.2003+03
14	.462+02	0.	.6773-01	.7493-01	.0000	.2318+03
15	.463+02	0.	.9673-01	.7373-01	.0000	.1823+03
16	.480+02	0.	.9673-01	.7209-01	.0000	.1480+03
17	.498+02	0.	.9673-01	.7238-01	.0000	.1261+03
18	.522+02	0.	.9673-01	.7179-01	.0000	.1086+03
19	.544+02	0.	.9673-01	.7119-01	.0000	.6123+02
20	.702+02	0.	.9673-01	.7077-01	.0000	.7818+02
21	.100+03	0.	.9673-01	.7043-01	.0000	.6405+02
22	.101+03	0.	.1019+00	.7367-01	.0000	.1068+03
23	.101+03	0.	.1022+00	.7750-01	.0000	.1425+03
24	.103+03	0.	.1241+00	.8407-01	.0000	.1976+03
25	.104+03	0.	.1468+00	.9192-01	.0000	.2384+03
26	.106+03	0.	.1698+00	.9788-01	.0000	.2631+03
27	.108+03	0.	.1923+00	.1026+00	.0000	.2471+03
28	.110+03	0.	.2156+00	.1060+00	.0000	.2507+03
29	.110+03	0.	.2156+00	.1052+00	.0000	.2031+03
30	.112+03	0.	.2156+00	.1044+00	.0000	.1740+03
31	.114+03	0.	.2156+00	.1035+00	.0000	.1463+03
32	.116+03	0.	.2156+00	.1026+00	.0000	.1205+03
33	.124+03	0.	.2156+00	.1020+00	.0000	.1080+03
34	.134+03	0.	.2156+00	.1015+00	.0000	.0608+02
35	.166+03	0.	.2156+00	.1009+00	.0000	.0216+02
36	.167+03	0.	.2220+00	.1021+00	.0000	.1137+03
37	.168+03	0.	.2382+00	.1062+00	.0000	.1673+03
38	.170+03	0.	.2628+00	.1107+00	.0000	.2180+03
39	.172+03	0.	.2870+00	.1116+00	.0000	.2427+03
40	.173+03	0.	.3133+00	.1172+00	.0000	.2800+03
41	.175+03	0.	.3331+00	.1106+00	.0000	.2523+03
42	.178+03	0.	.3331+00	.1236+00	.0000	.2525+03
43	.181+03	0.	.4282+00	.1278+00	.0000	.2925+03

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## ORIGINAL DATA

WATERGILL IS AMO 3345-1  
 BALLS SPECULUS = .5000+06  
 VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

## TEST DATA

TYPE ... BIALYAL  
 INITIAL STRAIN RATE = .6700+00  
 PRESSURE = 0. MEG  
 TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	STRAIN INVARIANTS			CORRECTION DILATATION	OCTAHEDRAL STRAIN
		I1	I2	I3		
1	.000	.0000	.0000	.0000	.0000	.0000
2	.600+00	.8917-04	-4459-04	.0000	.6722-08	.5852-02
3	.140+01	.8863-03	-3941-03	.0000	.1000-03	.1622-01
4	.300+01	.2360-02	-1080-02	.0000	.2000-03	.2685-01
5	.360+01	.2453-02	-1077-02	.0000	.3000-03	.2682-01
6	.480+01	.2641-02	-1070-02	.0000	.5000-03	.2674-01
7	.780+01	.2734-02	-1067-02	.0000	.6000-03	.2670-01
8	.138+02	.2828-02	-1064-02	.0000	.7000-03	.2666-01
9	.250+02	.2828-02	-1064-02	.0000	.7000-03	.2666-01
10	.409+02	.2738-02	-1067-02	.0000	.6000-03	.2670-01
11	.414+02	.4664-02	-1432-02	.0000	.6000-03	.3004-01
12	.426+02	.6098-02	-2549-02	.0000	.1000-02	.4152-01
13	.444+02	.1222-01	-4706-02	.0000	.2000-02	.5631-01
14	.462+02	.2100-01	-7239-02	.0000	.7400-02	.7021-01
15	.468+02	.2300-01	-7132-02	.0000	.4700-02	.6088-01
16	.480+02	.2385-01	-7051-02	.0000	.9700-02	.6048-01
17	.498+02	.2436-01	-7001-02	.0000	.1030-01	.6028-01
18	.528+02	.2495-01	-6944-02	.0000	.1100-01	.6005-01
19	.538+02	.2554-01	-6887-02	.0000	.1170-01	.6002-01
20	.708+02	.2597-01	-6846-02	.0000	.1220-01	.6000-01
21	.100+03	.2631-01	-6813-02	.0000	.1260-01	.6000-01
22	.101+03	.2820-01	-7505-02	.0000	.1310-01	.7107-01
23	.101+03	.3174-01	-8466-02	.0000	.1470-01	.7660-01
24	.103+03	.4005-01	-1044-01	.0000	.1000-01	.8552-01
25	.104+03	.5486-01	-1349-01	.0000	.2750-01	.0030-01
26	.106+03	.7197-01	-1662-01	.0000	.9000-01	.1106+00
27	.108+03	.9071-01	-1983-01	.0000	.4000-01	.1227+00
28	.110+03	.1096+00	-2284-01	.0000	.6200-01	.1328+00
29	.110+03	.1104+00	-2268-01	.0000	.6200-01	.1328+00
30	.112+03	.1112+00	-2251-01	.0000	.6410-01	.1322+00
31	.114+03	.1121+00	-2232-01	.0000	.6530-01	.1320+00
32	.116+03	.1130+00	-2212-01	.0000	.6650-01	.1320+00
33	.124+03	.1136+00	-2190-01	.0000	.6730-01	.1320+00
34	.136+03	.1141+00	-2168-01	.0000	.6800-01	.1320+00
35	.160+03	.1147+00	-2175-01	.0000	.6800-01	.1320+00
36	.167+03	.1109+00	-2266-01	.0000	.7200-01	.1453+00
37	.168+03	.1320+00	-2530-01	.0000	.7830-01	.1480+00
38	.170+03	.1521+00	-2909-01	.0000	.8090-01	.1566+00
39	.172+03	.1732+00	-3300-01	.0000	.1020+00	.1603+00
40	.173+03	.1961+00	-3670-01	.0000	.1160+00	.1617+00
41	.175+03	.2155+00	-4059-01	.0000	.1300+00	.1623+00
42	.178+03	.2504+00	-4737-01	.0000	.1530+00	.2157+00
43	.181+03	.3103+00	-5472-01	.0000	.1755+00	.2378+00

# SUMMARY OF TEST NO. RM602

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## MATERIAL DATA

MATERIAL IS AMH 3345-1

BULK MODULUS = 5000+06

VOLUMETRIC EXPANSION COEFFICIENT = .000-03

## TEST DATA

TYPE ... BIAXIAL

INITIAL STRAIN RATE = .0700+00

PRESSURE = 0. PSIG

TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	STRAINS (CALCULATED)			YIELD STRESS (S1 - S22)	
			F11	F22	F33	E12	
1	.000	0.	.0000	.0000	.0000	.0000	.0000
2	.130+01	0.	.1553-01	-.1506-01	.0000	.0000	.0000
3	.230+01	0.	.2023-01	-.2761-01	.0000	.0000	.0000
4	.378+01	0.	.4710-01	-.3940-01	.0000	.0000	.0000
5	.559+01	0.	.6425-01	-.5552-01	.0000	.0000	.0000
6	.670+01	0.	.7058-01	-.6505-01	.0000	.0000	.0000
7	.858+01	0.	.1000+00	-.7703-01	.0000	.0000	.0000
8	.910+01	0.	.1000+00	-.7501-01	.0000	.0000	.0000
9	.104+02	0.	.1000+00	-.7507-01	.0000	.0000	.0000
10	.122+02	0.	.1000+00	-.7448-01	.0000	.0000	.0000
11	.146+02	0.	.1000+00	-.7406-01	.0000	.0000	.0000
12	.206+02	0.	.1000+00	-.7347-01	.0000	.0000	.0000
13	.326+02	0.	.1000+00	-.7207-01	.0000	.0000	.0000
14	.642+02	0.	.1000+00	-.7271-01	.0000	.0000	.0000
15	.846+02	0.	.1056+00	-.7576-01	.0000	.0000	.0000
16	.090+02	0.	.1200+00	-.8329-01	.0000	.0000	.0000
17	.710+02	0.	.1354+00	-.8653-01	.0000	.0000	.0000
18	.722+02	0.	.1506+00	-.9471-01	.0000	.0000	.0000
19	.740+02	0.	.1737+00	-.1016+00	.0000	.0000	.0000
20	.743+02	0.	.1854+00	-.1040+00	.0000	.0000	.0000
21	.742+02	0.	.1854+00	-.1034+00	.0000	.0000	.0000
22	.748+02	0.	.1854+00	-.1029+00	.0000	.0000	.0000
23	.770+02	0.	.1854+00	-.1020+00	.0000	.0000	.0000
24	.800+02	0.	.1854+00	-.1012+00	.0000	.0000	.0000
25	.860+02	0.	.1854+00	-.1003+00	.0000	.0000	.0000
26	.920+02	0.	.1854+00	-.9857-01	.0000	.0000	.0000
27	.116+03	0.	.1854+00	-.9919-01	.0000	.0000	.0000
28	.134+03	0.	.1854+00	-.9981-01	.0000	.0000	.0000
29	.135+03	0.	.1017+00	-.1012+00	.0000	.0000	.0000
30	.153+03	0.	.2076+00	-.1057+00	.0000	.0000	.0000
31	.137+03	0.	.2236+00	-.1008+00	.0000	.0000	.0000
32	.139+03	0.	.2400+00	-.1146+00	.0000	.0000	.0000
33	.141+03	0.	.2724+00	-.1145+00	.0000	.0000	.0000
34	.144+03	0.	.3150+00	-.1248+00	.0000	.0000	.0000
35	.147+03	0.	.3583+00	-.1279+00	.0000	.0000	.0000
36	.150+03	0.	.4028+00	-.1319+00	.0000	.0000	.0000
37	.152+03	0.	.4391+00	-.1350+00	.0000	.0000	.0000

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## MATERIAL DATA

MATERIAL IS AN: 3345-1  
 BULK MODULUS = .5000+06  
 VOLUMETRIC EXPANSION COEFFICIENT = .1900-03

## TEST DATA

TYPE ... BIAXIAL  
 INITIAL STRAIN RATE = .4700+00  
 PRESSURE = 0. PSIG  
 TEMPERATURE IS CONSTANT

DATA POINT	TIME SFC.	I1	STRAIN INVARIANTS I2	I3	CORRECTED DILATATION	OCTAHEDRAL STRAIN
1	.000	.0000	.0000	.0000	.0000	.0000
2	.130+01	.4670-03	-.2139-03	.0000	.1553-07	.1245-01
3	.250+01	.1614-02	-.9069-03	.0000	.2022-07	.2321-01
4	.370+01	.3697-02	-.1160-02	.0000	.3000-03	.3365-01
5	.550+01	.8735-02	-.3567-02	.0000	.1600-02	.4054-01
6	.670+01	.1353-01	-.5111-02	.0000	.3300-02	.5879-01
7	.450+01	.2247-01	-.7024-02	.0000	.6000-02	.7500-01
8	.010+01	.2440-01	-.7622-02	.0000	.0200-02	.7221-01
9	.100+02	.2533-01	-.7537-02	.0000	.1020-01	.7100-01
10	.122+02	.2502-01	-.7470-02	.0000	.1000-01	.7164-01
11	.146+02	.2624-01	-.7436-02	.0000	.1140-01	.7140-01
12	.206+02	.2603-01	-.7377-02	.0000	.1210-01	.7127-01
13	.326+02	.2743-01	-.7326-02	.0000	.1270-01	.7107-01
14	.602+02	.2769-01	-.7300-02	.0000	.1300-01	.7097-01
15	.406+02	.2670-01	-.7097-02	.0000	.1370-01	.7435-01
16	.690+02	.3710-01	-.1003-01	.0000	.1600-01	.8361-01
17	.710+02	.4507-01	-.1212-01	.0000	.2400-01	.0246-01
18	.722+02	.5560-01	-.1426-01	.0000	.2730-01	.1010+00
19	.740+02	.7215-01	-.1765-01	.0000	.3620-01	.1137+00
20	.749+02	.8145-01	-.1020-01	.0000	.4200-01	.1107+00
21	.752+02	.8206-01	-.1917-01	.0000	.4200-01	.1105+00
22	.750+02	.8267-01	-.1806-01	.0000	.4360-01	.1103+00
23	.770+02	.8343-01	-.1892-01	.0000	.4460-01	.1100+00
24	.800+02	.8427-01	-.1876-01	.0000	.4570-01	.1197+00
25	.860+02	.8511-01	-.1861-01	.0000	.4680-01	.1184+00
26	.900+02	.8587-01	-.1847-01	.0000	.4700-01	.1181+00
27	.116+03	.8626-01	-.1839-01	.0000	.4830-01	.1180+00
28	.134+03	.8664-01	-.1832-01	.0000	.4800-01	.1179+00
29	.135+03	.8057-01	-.1840-01	.0000	.5050-01	.1215+00
30	.136+03	.1010+00	-.2104-01	.0000	.5640-01	.1301+00
31	.137+03	.1130+00	-.2456-01	.0000	.6270-01	.1387+00
32	.139+03	.1334+00	-.2843-01	.0000	.7300-01	.1513+00
33	.141+03	.1543+00	-.3231-01	.0000	.8600-01	.1630+00
34	.144+03	.1902+00	-.3930-01	.0000	.1060+02	.1850+00
35	.147+03	.2309+00	-.4566-01	.0000	.1310+00	.2056+00
36	.150+03	.2700+00	-.5311-01	.0000	.1530+00	.2274+00
37	.152+03	.3042+00	-.5928-01	.0000	.1710+00	.2451+00

MATERIAL DATA

PARTIAL TS ANI 3345-1  
BULK MODULUS = 5000+06  
VOLUMETRIC EXPANSION COEFFICIENT = .1000-03

TEST DATA

TYPE ... BIAXIAL  
INITIAL STRAIN RATE = .2660-00  
PRESSURE = 0. PSIG  
TEMPERATURE IS CONSTANT

DATA POINT	TIME SFC.	TEMP. DEG.-F	F11	F22	STRAINS (CALCULATED) E33	F12	TRUE STRESS (S11 - S22)
1	.000	0.	.0000	.0000	.0000	.0000	.0000
2	.456+01	0.	.2042-01	-.1062-01	.0000	.0000	.0501+02
3	.636+01	0.	.2050-01	-.2605-01	.0000	.0000	.0755+02
4	.376+01	0.	.3050-01	-.3641-01	.0000	.0000	.0725+02
5	.149+02	0.	.6750-01	-.5706-01	.0000	.0000	.1054+02
6	.200+02	0.	.6627-01	-.7534-01	.0000	.0000	.1763+02
7	.260+02	0.	.1257+00	-.8035-01	.0000	.0000	.1032+02
8	.320+02	0.	.1550+00	-.9729-01	.0000	.0000	.1000+02
9	.403+02	0.	.1066+00	-.1044+00	.0000	.0000	.2055+02
10	.440+02	0.	.2101+00	-.1096+00	.0000	.0000	.2006+02
11	.509+02	0.	.2504+00	-.1143+00	.0000	.0000	.2114+02
12	.560+02	0.	.2033+00	-.1100+00	.0000	.0000	.2142+02
13	.620+02	0.	.3169+00	-.1216+00	.0000	.0000	.2150+02
14	.600+02	0.	.3513+00	-.1247+00	.0000	.0000	.2172+02
15	.740+02	0.	.3064+00	-.1276+00	.0000	.0000	.2106+02
16	.000+02	0.	.4221+00	-.1305+00	.0000	.0000	.2170+02



SUMMARY OF TEST NO. R00603

MATERIAL DATA

MATERIAL IS ANI 3335-1  
 BULK MODULUS = .5000+06  
 VOLUMETRIC EXPANSION COEFFICIENT = .1800-03  
 TYPE ... PLASTIC  
 INITIAL STRAIN RATE = .2660+00  
 PRESSURE = 0. PSTG  
 TEMPERATURE IS CONSTANT

TEST DATA

DATA POINT	TIME SFC.	11	STRAIN INVARIANTS 12	13	CORRECTED DILATATION	OCTAHEDRAL STRAIN
1	.000	.0000	.0000	.0000	.0000	.0000
2	.456+01	.0013-03	-.4006-03	.0020	.2042-07	.1635-01
3	.636+01	.1641-02	-.7707-03	.0000	.1000-03	.2660-01
4	.876+01	.3183-02	-.1441-02	.0000	.3000-03	.3103-01
5	.148+02	.0721-02	-.3910-02	.0000	.1000-02	.5126-01
6	.208+02	.2093-01	-.7253-02	.0000	.6400-02	.7023-01
7	.268+02	.3732-01	-.1110-01	.0000	.1500-01	.8782-01
8	.328+02	.5050-01	-.1516-01	.0000	.2780-01	.1042+00
9	.388+02	.8217-01	-.1049-01	.0000	.4230-01	.1204+00
10	.448+02	.1085+00	-.2390-01	.0000	.5000-01	.1362+00
11	.508+02	.1361+00	-.2961-01	.0000	.7600-01	.1523+00
12	.568+02	.1653+00	-.3343-01	.0000	.9400-01	.1684+00
13	.628+02	.1953+00	-.3854-01	.0000	.1120+00	.1849+00
14	.688+02	.2266+00	-.4380-01	.0000	.1705+00	.2015+00
15	.748+02	.2587+00	-.4931-01	.0000	.1490+00	.2185+00
16	.808+02	.2917+00	-.5507-01	.0000	.1675+00	.2358+00

END R00604

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## SUMMARY OF TEST NO. 000604

## TEST DATA

MATERIAL IS ANA 3335-1  
 BULK MODULUS =  $5.000 \times 10^6$   
 VOLUMETRIC EXPANSION COEFFICIENT =  $.1000 \times 10^{-3}$

TYPE ... BICRYSTAL  
 INITIAL STRAIN RATE =  $.4700 \times 10^{-1}$   
 PRESSURE = 0. PSIG  
 TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	F11	F22	STRAINS (CALCULATED) E33	E12	TRUE STRESS (SI) - (PSI)
1	.000	0.	.0000	.0000	.0000	.0000	.0000
2	.180+02	0.	.2030-01	-.1051-01	.0000	.0000	.2856+02
3	.360+02	0.	.3406-01	-.3109-01	.0000	.0000	.4758+02
4	.480+02	0.	.5504-01	-.4013-01	.0000	.0000	.7705+02
5	.740+02	0.	.9089-01	-.7341-01	.0000	.0000	.1226+03
6	.105+03	0.	.1279+00	-.9157-01	.0000	.0000	.1481+03
7	.133+03	0.	.1660+00	-.1035+00	.0000	.0000	.1571+03
8	.168+03	0.	.2052+00	-.1120+00	.0000	.0000	.1637+03
9	.198+03	0.	.2453+00	-.1186+00	.0000	.0000	.1679+03
10	.228+03	0.	.2870+00	-.1239+00	.0000	.0000	.1714+03
11	.259+03	0.	.3296+00	-.1287+00	.0000	.0000	.1742+03
12	.288+03	0.	.3733+00	-.1332+00	.0000	.0000	.1768+03

## MATERIAL DATA

MATERIAL IS ARL 335-1

BULK MODULUS = .5000E06

VOLUMETRIC EXPANSION COEFFICIENT = .1800E-03

## TEST DATA

TYPE ... BIAXIAL  
INITIAL STRAIN RATE = .2700E+00  
PRESSURE = 200. PCIF  
TEMPERATURE IC CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	F11	F22	STRAINS (CALCULATED) E33	F12	TRUE STRESS (S11 - S22)
1	.000	0.	-.2000E-03	-.2000E-03	.0000	.0000	.0000
2	.264E+01	0.	.2071E-01	-.2042E-01	.0000	.0000	.0677E+02
3	.444E+01	0.	.5060E-01	-.4604E-01	.0000	.0000	.1677E+03
4	.600E+01	0.	.6003E-01	-.6013E-01	.0000	.0000	.2144E+03
5	.624E+01	0.	.6003E-01	-.6004E-01	.0000	.0000	.2005E+03
6	.694E+01	0.	.6003E-01	-.6004E-01	.0000	.0000	.1760E+03
7	.804E+01	0.	.6003E-01	-.5005E-01	.0000	.0000	.1525E+03
8	.884E+01	0.	.6003E-01	-.5005E-01	.0000	.0000	.1444E+03
9	.128E+02	0.	.6003E-01	-.5005E-01	.0000	.0000	.1144E+03
10	.188E+02	0.	.6003E-01	-.6004E-01	.0000	.0000	.1045E+03
11	.309E+02	0.	.6003E-01	-.6013E-01	.0000	.0000	.0865E+02
12	.460E+02	0.	.6003E-01	-.6022E-01	.0000	.0000	.0310E+02
13	.464E+02	0.	.7476E-01	-.6452E-01	.0000	.0000	.1415E+03
14	.476E+02	0.	.8022E-01	-.7469E-01	.0000	.0000	.2213E+03
15	.488E+02	0.	.1039E+00	-.1040E-01	.0000	.0000	.2777E+03
16	.506E+02	0.	.1261E+00	-.9681E-01	.0000	.0000	.2937E+03
17	.520E+02	0.	.1428E+00	-.1046E+00	.0000	.0000	.2433E+03
18	.524E+02	0.	.1428E+00	-.1041E+00	.0000	.0000	.2062E+03
19	.536E+02	0.	.1428E+00	-.1040E+00	.0000	.0000	.2410E+03
20	.554E+02	0.	.1428E+00	-.1041E+00	.0000	.0000	.2325E+03
21	.570E+02	0.	.1428E+00	-.1042E+00	.0000	.0000	.2122E+03
22	.634E+02	0.	.1428E+00	-.1046E+00	.0000	.0000	.1807E+03
23	.753E+02	0.	.1428E+00	-.1052E+00	.0000	.0000	.1706E+03
24	.938E+02	0.	.1428E+00	-.1057E+00	.0000	.0000	.1401E+03
25	.112E+03	0.	.1428E+00	-.1059E+00	.0000	.0000	.1802E+03
26	.112E+03	0.	.1488E+00	-.1088E+00	.0000	.0000	.2020E+03
27	.114E+03	0.	.1442E+00	-.1158E+00	.0000	.0000	.2067E+03
28	.115E+03	0.	.1476E+00	-.1248E+00	.0000	.0000	.1572E+03
29	.117E+03	0.	.2113E+00	-.1324E+00	.0000	.0000	.2110E+03
30	.119E+03	0.	.2355E+00	-.1328E+00	.0000	.0000	.2086E+03
31	.120E+03	0.	.2437E+00	-.1409E+00	.0000	.0000	.2435E+03
32	.120E+03	0.	.2519E+00	-.1427E+00	.0000	.0000	.2500E+03
33	.121E+03	0.	.2684E+00	-.1465E+00	.0000	.0000	.2086E+03
34	.123E+03	0.	.2935E+00	-.1524E+00	.0000	.0000	.2670E+03
35	.126E+03	0.	.3276E+00	-.1601E+00	.0000	.0000	.2907E+03



# SUMMARY OF TEST NO. H10601

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## MATERIAL DATA

MATERIAL IS ABR 3345-1  
BULK MODULUS = .5000x10<sup>6</sup>  
VOLUMETRIC EXPANSION COEFFICIENT = .1900x10<sup>-3</sup>

## TEST DATA

TYPE ... BIAXIAL  
INITIAL STRAIN RATE = .6700x10<sup>0</sup>  
PRESSURE = 200. PSIG  
TEMPERATURE 1°C CONSTANT

DATA POINT	TIME SEC.	I1	STRAIN INVARIANTS I2	I3	CORRECTION DILATATION	OCTAHEDRAL STRAIN
1	.000	-.4000-03	.4000-07	.0000	-.4000-03	.9828-08
2	.264x01	.1289-02	-.0443-03	.0000	-.4000-03	.2374-01
3	.444x01	.0559-02	-.2330-02	.0000	-.0005-04	.3647-01
4	.600x01	.0002-02	-.4151-02	.0000	.6001-03	.5277-01
5	.624x01	.0050-02	-.4145-02	.0000	.7001-03	.5274-01
6	.684x01	.0050-02	-.4145-02	.0000	.7001-03	.5274-01
7	.804x01	.0078-02	-.4139-02	.0000	.8001-03	.5270-01
8	.984x01	.0078-02	-.4139-02	.0000	.8001-03	.5270-01
9	.128x02	.0078-02	-.4139-02	.0000	.8001-03	.5270-01
10	.188x02	.0090-02	-.4145-02	.0000	.7001-03	.5270-01
11	.308x02	.0090-02	-.4151-02	.0000	.6001-03	.5277-01
12	.460x02	.0014-02	-.4157-02	.0000	.6001-03	.5281-01
13	.464x02	.1025-01	-.4823-02	.0000	.6001-03	.5651-01
14	.476x02	.1453-01	-.6664-02	.0000	.1200-02	.6700-01
15	.488x02	.1977-01	-.8733-02	.0000	.2300-02	.7687-01
16	.506x02	.2934-01	-.1221-01	.0000	.4000-02	.6128-01
17	.520x02	.3811-01	-.1404-01	.0000	.8200-02	.1014x00
18	.524x02	.4866-01	-.1486-01	.0000	.8000-02	.1012x00
19	.536x02	.5874-01	-.1485-01	.0000	.8000-02	.1012x00
20	.554x02	.6866-01	-.1486-01	.0000	.8200-02	.1012x00
21	.578x02	.7850-01	-.1488-01	.0000	.8200-02	.1012x00
22	.638x02	.8811-01	-.1494-01	.0000	.8200-02	.1014x00
23	.758x02	.9706-01	-.1502-01	.0000	.7500-02	.1014x00
24	.938x02	.9706-01	-.1508-01	.0000	.6000-02	.1014x00
25	.112x03	.3686-01	-.1512-01	.0000	.6600-02	.1014x00
26	.112x03	.8002-01	-.1620-01	.0000	.7600-02	.1064x00
27	.114x03	.4830-01	-.1602-01	.0000	.1030-01	.1144x00
28	.115x03	.6275-01	-.2341-01	.0000	.1580-01	.1284x00
29	.117x03	.7893-01	-.2798-01	.0000	.2270-01	.1414x00
30	.119x03	.9667-01	-.2770-01	.0000	.3080-01	.1584x00
31	.120x03	.1028x00	-.3432-01	.0000	.3360-01	.1588x00
32	.120x03	.1092x00	-.3504-01	.0000	.3660-01	.1631x00
33	.121x03	.1218x00	-.3933-01	.0000	.4230-01	.1718x00
34	.123x03	.1411x00	-.4474-01	.0000	.5030-01	.1851x00
35	.126x03	.1675x00	-.5245-01	.0000	.6080-01	.2030x00

SUMMARY OF TEST NO. 010602

MATERIAL DATA

MATERIAL IS ANA 3335-1  
 BULK MODULUS = .5000+06  
 VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

TEST DATA

TYPE ... BIAXIAL  
 INITIAL STRAIN RATE = .6700+00  
 PRESSURE = 250. PSTG  
 TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	F11	F22	STRAINS (CALCULATED) E11	F12	TRUE STRESS (C11 - C22)
1	.000	0.	-.2500-03	-.2500-03	.0000	.0000	.0000
2	.228+01	0.	.2553-01	-.2476-01	.0000	.0000	.6768+02
3	.528+01	0.	.6043-01	-.5036-01	.0000	.0000	.1506+03
4	.648+01	0.	.7071-01	-.6517-01	.0000	.0000	.1051+03
5	.048+01	0.	.1112+00	-.0973-01	.0000	.0000	.2762+03
6	.125+02	0.	.1488+00	-.1003+00	.0000	.0000	.7315+03
7	.155+02	0.	.1875+00	-.1247+00	.0000	.0000	.7641+03
8	.185+02	0.	.2274+00	-.1378+00	.0000	.0000	.7800+03
9	.209+02	0.	.2600+00	-.1472+00	.0000	.0000	.8013+03
10	.239+02	0.	.3010+00	-.1581+00	.0000	.0000	.8097+03
11	.269+02	0.	.3449+00	-.1600+00	.0000	.0000	.8100+03

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# SUMMARY OF TEST NO. R10602

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## MATERIAL DATA

MATERIAL IS AN: 3325-1  
 BULK MODULUS = .5000+06  
 VOLUMETRIC EXPANSION COEFFICIENT = .1000-03

## TEST DATA

TYPE ... BIAXIAL  
 INITIAL STRAIN RATE = .2700+00  
 PRESSURE = 250. PSIG  
 TEMPERATURE IS CONSTANT

DATA POINT	TIME SFC.	I1	STRAIN INVARIANTS I2	I3	CORRECTION DILATATION	OCTAHEDRAL STRAIN
1	.000	-.5000-03	.6250-07	.0000	-.5000-03	.1170-03
2	.228+01	.7545-03	-.6321-03	.0000	-.5000-03	.2053-01
3	.528+01	.6171-02	-.3285-02	.0000	-.4009-03	.4080-01
4	.648+01	.9536-02	-.4469-02	.0000	-.1009-03	.5715-01
5	.948+01	.2146-01	-.0977-02	.0000	.1500-02	.8218-01
6	.125+02	.3953-01	-.1625-01	.0000	.7000-02	.1054+00
7	.155+02	.6280-01	-.2338-01	.0000	.1590-01	.1283+00
8	.185+02	.8952-01	-.3134-01	.0000	.2650-01	.1504+00
9	.205+02	.1128+00	-.3828-01	.0000	.3560-01	.1684+00
10	.239+02	.1438+00	-.4773-01	.0000	.4720-01	.1082+00
11	.269+02	.1750+00	-.5827-01	.0000	.5770-01	.2138+00

END ADD R10603

# SUMMARY OF TEST NO. R10A03

PAGE FIVE - 1

## MATERIAL DATA

MATERIAL IS ANI 3345-1  
 BULK MODULUS = .500+00  
 VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

## TEST DATA

TYPE ... BIAXIAL  
 INITIAL STRAIN RATE = .6700+00  
 PRESSURE = 500. PSTG  
 TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	STRAINS (CALCULATED)	F12	YIELD STRESS (S11 - S22)
1	.000	0.	-5000-03	.0000	.0000
2	.120+01	0.	-1363-01	.0000	.5371+02
3	.300+01	0.	-3237-01	.0000	.1302+03
4	.480+01	0.	-4087-01	.0000	.1091+03
5	.750+01	0.	-7644-01	.0000	.2009+03
6	.100+02	0.	-9048-01	.0000	.3804+03
7	.138+02	0.	-1103+00	.0000	.4915+03
8	.162+02	0.	-1364+00	.0000	.6731+03
9	.192+02	0.	-1488+00	.0000	.8916+03
10	.198+02	0.	-1517+00	.0000	.8946+03
11	.216+02	0.	-1604+00	.0000	.5032+03

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# SUMMARY OF TEST NO. R10601

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## MATERIAL DATA

MATERIAL IS ABR 3335-1

BULK MODULUS = .5000+06

VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

## TEST DATA

TYPE ... BIAXIAL

INITIAL STRAIN RATE = .6700+00

PRESSURE = 500. PSIG

TEMPERATURE IS CONSTANT

DATA POINT	TIME SFC.	11	STRAIN INVARIANTS I2	I3	CORRECTED DILATATION	OCTAHEDRAL STRAIN
1	.000	-.1000-02	-.2500-06	.0000	-.1000-02	.2357-03
2	.120+01	-.6456-03	-.1766-03	.0000	-.1000-02	.1097-01
3	.300+01	.1172-02	-.1086-02	.0000	-.1000-02	.2601-01
4	.480+01	.4637-02	-.2719-02	.0000	-.7099-03	.8263-01
5	.760+01	.1391-01	-.6906-02	.0000	.1001-03	.6817-01
6	.108+02	.2783-01	-.1266-01	.0000	.2500-02	.9282-01
7	.138+02	.4609-01	-.1973-01	.0000	.6600-02	.1167+00
8	.168+02	.6819-01	-.2701-01	.0000	.1230-01	.1401+00
9	.192+02	.8800-01	-.3523-01	.0000	.1740-01	.1588+00
10	.198+02	.9327-01	-.3715-01	.0000	.1880-01	.1634+00
11	.216+02	.1093+00	-.4326-01	.0000	.2250-01	.1775+00

4 400 R10604

# SUMMARY OF TEST NO. R10604

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## MATERIAL DATA

MATERIAL IS ANI 3335-1  
 RULY MODULUS = .5000+06  
 VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

## TEST DATA

TYPE ... BIAXIAL  
 INITIAL STRAIN RATE = .6700+00  
 PRESSURE = 1000. PSIG  
 TEMPERATURE IS CONSTANT

DATA POINT	TIME SEC.	TEMP. DEG.-F	F11	F22	E33 (CALCULATED)	E12	TRUE STRESS (S11 - S22)
1	.000	0.	-.1000-02	-.1000-02	.0000	.0000	.0000
2	.480+01	0.	.5398-01	-.5053-01	.0000	.0000	.1991+03
3	.660+01	0.	.7534-01	-.6704-01	.0000	.0000	.2706+03
4	.840+01	0.	.9711-01	-.8265-01	.0000	.0000	.3390+03
5	.114+02	0.	.1243+00	-.1066+00	.0000	.0000	.4350+03
6	.144+02	0.	.1726+00	-.1281+00	.0000	.0000	.5184+03
7	.174+02	0.	.2120+00	-.1477+00	.0000	.0000	.5783+03
8	.204+02	0.	.2525+00	-.1653+00	.0000	.0000	.6260+03
9	.234+02	0.	.2942+00	-.1814+00	.0000	.0000	.6587+03
10	.246+02	0.	.3112+00	-.1875+00	.0000	.0000	.6574+03

# SUMMARY OF TEST NO. R10604

PAGE R10604 - 2

## MATERIAL DATA

MATERIAL IS AMR 3335-1

BULK MODULUS = 5000+06

VOLUMETRIC EXPANSION COEFFICIENT = .1800-03

## TEST DATA

TYPE ... BIAXIAL

INITIAL STRAIN RATE = .6700+00

PRESSURE = 1000. PSIG

TEMPERATURE IS CONSTANT

DATA POINT	TIME SFC.	I1	STRAIN INVARIANTS I2	I3	CORRECTED DILATATION	OCTAHEDRAL STRAIN
1	.000	-.2000-02	1000-05	.0000	-.2000-02	.9714-03
2	.480+01	-.3457-02	-.2728-02	.0000	-.2000-02	.4267-01
3	.660+01	.8303-02	-.5051-02	.0000	-.1800-02	.5816-01
4	.840+01	.1445-01	-.8026-02	.0000	-.1600-02	.7346-01
5	.114+02	.2764-01	-.1432-01	.0000	-.0899-03	.9857-01
6	.144+02	.4443-01	-.2211-01	.0000	.2002-03	.1232+00
7	.174+02	.6431-01	-.3130-01	.0000	.1700-02	.1876+00
8	.204+02	.8727-01	-.4173-01	.0000	.3800-02	.1718+00
9	.234+02	.1128+00	-.5337-01	.0000	.6000-02	.1960+00
10	.246+02	.1236+00	-.5835-01	.0000	.6900-02	.2057+00

Q ADD 100700

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